SOLAR FINANCING: INDIA

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This article is on solar finance in the context of India and comparing with financial innovation in developed markets. This article covers basic ideas of solar PV capex / opex / production yield / monetization, project and equity IRR with and without debt, risk/reward characteristics that form the basis of finance, and recourse/non-recourse financing ideas, how such mechanisms can come together into business models such as third-party ownership / solar-as-a-service (solar PPA, lease), solar loans, solar securitization, peer-to-peer financing, yield-cos, solar financing for the poor/offgrid (eg: pioneered by Selco) etc.

Let's start with the basics of solar economics in India. You want to put up a solar PV plant (either small scale rooftop, eg 3-10 kWp, medium scale (50 kWp-1MWp) or utility scale 50 MWp+). a 1-5kWp system installed today in costs (i.e. CAPEX) Rs. 1L / kWp (~$1.5/Wp), a 10-25kWp system costs Rs. 75-80,000/kWp a 50 kWp system costs Rs. 65-70,000 / kWp whereas a large farm (MWp scale) costs between Rs. 43,000-50,000/ installed including cheap land. {this does not include network transmission costs, and may include some evacuation costs}. India has perhaps the lowest installed costs of solar PV in the world today and it is getting better with scale, local manufacturing, better supply chains etc.

A well maintained system (eg: clearing dust, avoiding shadows etc) yields 4.5 - 5kWh/day/kWp (18.75% - 20.8% capacity factor) due to the good amount and distribution of solar irradiance across India... India has *"twice the sunshine, half the costs..."* compared to Japan said by Masayoshi Son, Softbank CEO. This translates to 135 - 150 units/month/kWp (1 unit = 1kWh), monthly energy yield, or 1642 - 1825 kWh/year/kWp, i.e. annual energy yield. If you have higher degree of power cuts or curtailment, shadowing obstructions for part of the day, poorly balanced system (different panels produce differently) or do not clean panels well, the energy yield can drop to 4 kWh/day/kWp. The life of the system can be 25 years or more (solar PV modules are rated for 80% production at 25 years, (good) inverters need to be replaced once in 10 years) if well maintained.

The energy can be monetized on average today with power purchase agreement rate (PPA rate) at about Rs. 4.5-5.5/kWh wholesale (via PPAs with NTPC or state DISCOMs) and Rs. 6.5-7.5/kWh retail (eg: via net metering and other rooftop solar policies). If you multiply by the annual energy yield (lets pick 1825 kWh/year/kWp) with the PPA rate (lets pick average Rs. 5 / kWh wholesale and Rs. 7 / kWh retail), we get an annual revenue yield of Rs. 9125 / kWp/ year (wholesale), and Rs. 12,775 / kWp / year (retail). Remember that our capital expenses (CAPEX) numbers above ranged from Rs. 48,000/kWp (wholesale, MWp scale) to Rs. 70,000/kWp (50 kWp scale) and Rs. 1 lakh/kWp (1-5 kWp scale rooftop). If the annual operating expenses are 2% of CAPEX, we get an OPEX of Rs. 960 / kWp / year (wholesale) and Rs. 1500/kWp/year (retail, assuming a 75K average capex for businesses). Subtract this out from annual revenue yield, we get EBITDA (earnings before interest, tax, depreciation, amortization) of Rs. 8165/kWp/year (wholesale) and Rs. 11275 / kWp/year (retail or rooftop).

Divide EBITDA by CAPEX to get annual earnings yield: (8165 / 48000 =) 17% wholesale, and (11275 / 70000 or 11275 / 100,000) = 16% (for a 50 kWp scale system) and 11.275% (for a 1-5kWp system). The earnings yield on invested capital (before depreciation or subsidies and financing) therefore rises from 11% small-scale retail to 16% medium scale rooftop to 17% utility scale.

Now that we understand how exactly our asset is a "productive" asset yielding regular cash flows, lets now think about financing. Financing is a function of risk and return; and relative to alternative returns (opportunity costs) on capital. In other words, if you as a residential investor were to take the same invested capital and put it in a bank's fixed deposit, you would get about 7.0-8.5% for 5 years in many Indian banks (see bankbazaar, or moneycontrol). In other words, if you fund the entire solar PV system with your own cash (i.e. 100% equity financing and own the system), trust the production yield / PPA numbers above, your PPA counterparty (i.e. the DISCOM) pays you on time, and you maintain the system well, you can expect a return of 11-17%. Note that the performance of the system diminishes by 0.5% per year over 20-25 years. If you compute an internal rate of return (i.e. project-IRR which in this case is also the equity-IRR), over a long term, i.e. 25-30 years, it will range from 10-16%. [Note: some of these numbers change if you assume an aggressive escalator for OPEX, and/or higher module degradation parameters etc. Also IRR is a function of the number of years: fewer years (eg: 5 years) will give you a fairly low IRR.]

Compare 10-16% IRR with 7-8.5% opportunity cost (i.e. FD rate for retail households), and 15% equity cost of capital for large-scale systems, we find that the economics are just about breakeven (3% spread for retail and 1% spread for large-scale). Observe that small-scale solar returns has lower returns and IRR, even with higher EBITDA and revenue yield since the cost of the system is almost twice that of utility scale and 33-50%

above medium-scale rooftop sector. However since their opportunity costs (eg: fixed deposit rates) are lower, it is still a modest deal (positive economic value)!

The government policies on accelerated depreciation (eg: 80% in year 1; and 80% on remaining (i.e. .8x 0.2 = 16% in year 2 and so on - assuming you have other sources of earnings to offset the depreciation... AD rates are reduced to 40% from 2017), the proposed 30% MNRE subsidy for residential sector, in some states there is no tax on residential PPA inflows (eg: in Karnataka) for 10 years, UDAY reforms enforcing renewable purchase obligations (RPOs), and ensuring counterparties like NTPC or DISCOMs pay regularly and on time (eg: the UDAY reforms increase DISCOM's capacity to pay you by reducing their debt, and enforcing RPOs) can significantly improve these economics to about (note: IRR computed for 15+ years) 14-15% project IRR for residential, 20-22% project IRR for medium-scale rooftop and large-scale utility plants. Both these long term IRR numbers offer positive economic returns when considering opportunity costs (about 7 - 8.5% in residential FDs; and 15% cost of equity for commercial / utility scale for this level of riskiness in cash flows).

So, what are the risks associated with the cash flows above? The sun rises everyday with 100% probability - zero risk there! However, there may be clouds on specific days, aerosols / smog in urban areas, unexpected shadowing artifacts (neighbor's building), uneven dust / soiling and uneven balancing that reduces performance, panels that fail (quality and warranty matters!), panels could be stolen or damaged by vandalism etc. On the financial side, the DISCOMs or NTPC may choose not to pay you or dispute the amount you produced/fed-in etc. These are manageable, low risks, especially if you own the system and can put in good operational, security, contractual and mitigation mechanisms. Government policy stance and enforcement is also key. Note that the government policies both increase returns (via AD, subsidies etc) and reduce risks (via

UDAY, escrow accounts, routing money via NTPC in JNNSM, Jawaharlal Nehru National Solar Mission, i.e. solar procurement). Once the solar PV system is commissioned (i.e. land acquisition, contracting / bidding risks are over), the operational risks (with good management) appear significantly lower than the general risk levels in the economy.

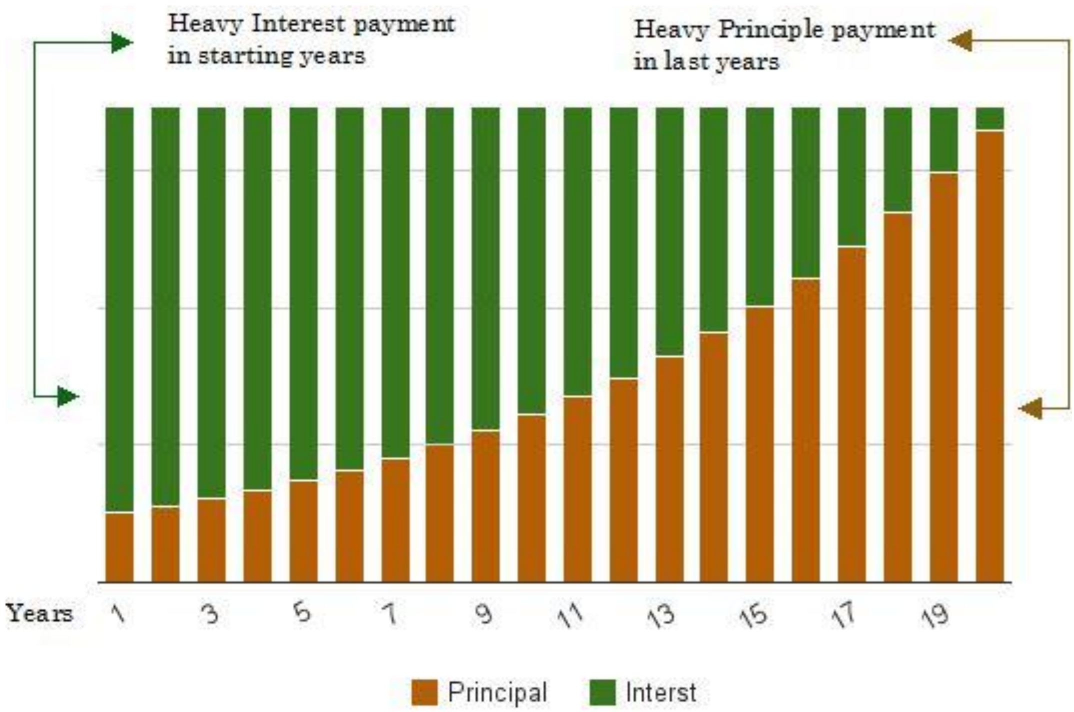
So far, we have considered equity financing (i.e. 100% paid by your own or your company's own spare cash). Suppose you want to set up a 500 MW farm, this will cost a capex of $375 million (at $0.75/Wp) like the SunEdison Rs. 4.63/unit bid for NTPC. Perhaps you don't have so much spare cash lying around, and therefore you need to raise debt. Remember that we started off with a 20% IRR project. If we fund 70% of it with debt, and 30% equity. Since interest expenses (for corporates) are tax deductible, a 14% pre-tax debt, at 30% tax rate is 9.8% post-tax interest rate. Now if you ask what is the levered or equity-IRR,we have to compute the cash flows to equity. This involves subtracting out debt service costs (principal & interest payments) for the term of the loan (eg: for 70% CAPEX) from the EBITDA, and allocating the equity portion of CAPEX (i.e. 30% of CAPEX) as the (negative, i.e. cash flow out) starting value in year 0.

This calculation shows an interesting phenomenon. If residential systems do NOT have subsidies (i.e. 30%), and pay roughly Rs. 1L / kWp, then taking on debt even up to 70% does NOT increase the long-term Equity-IRR above Project-IRR significantly. This is because short term Project IRRs can be quite low (3-5% for 10 years) for unsubsidized, high cost residential. The only way to increase P-IRRs in unsubsidized small-scale residential systems is to increase feed-in tariffs (eg: Rs. 8/kWh and beyond).

However, for medium-scale commercial and utility-scale settings, the long-term IRR (i.e. 20-30 year IRRs) can be amplified from 15-16% to about 25+% by taking on 15-20 year debt at 10% (post-tax). Depreciation (if cash flows are sufficient to utilize them) also boosts the returns, and magnifies the ratio of Equity-IRR to Project-IRR.

This boost in equity IRR is the "allure" of debt financing and high leverage ratios (70:30) for a significant term 15-20 years and why significant long-term debt-financing is sought by solar PV developers. Financiers are attracted to financing for several reasons: low overall risks (compared to say steel sector etc which are NPA ridden!), and if they can audit production, get a slice of incoming monetized production revenue directly from escrow accounts from government payments, this is almost like lending to the government at a higher interest rate.

However life is not this simple. First, the leverage (E-IRR to P-IRR) kicks in only when the capital costs are lower, and yields & monetization are good. Second, longer tenor loans are harder to obtain (esp from banks) in India, and requires some refinancing activity to emulate. Maintaining a high D/E ratio for a long term requires significant financial strength, operating excellence and financial engineering expertise. Most banks have asset / liability mismatch issues (eg: most fixed deposits (FDs) - their source of cash - are 5 years are less!), and give debt for 10-15 years max. Raising 25 year debt requires international capital or special infrastructure fund raising vehicles. Another option is to raise debt for 15 years; and re-finance the debt after 10 years for a 15 year period. If you look at your EMI (equated monthly installment) details, which includes both interest and principal repayment, the principal component of EMI tends to grow in the later stages of your loan term (eg: see JagoInvestor's site, reproduced below).



By doing this re-financing of your debt after 10 years, you are taking some interest rate and refinancing risk, and higher principal payments, but you can "emulate" a debt-equity ratio that is levered > 50-50 Debt/Equity over the 25 years of the horizon (i.e. you can get to 30%+ equity IRR or levered IRR). Also, by showing production and monetization yield data and regular EMI payment track records, the refinancing institution (perhaps the same bank) can gain confidence that their risks are low. This is what good CFOs do.

Second, the collateral we have assumed for 14% pre-tax interest rate (or 9.8% post-tax) is just the solar PV system, i.e. the banks or financiers do not have a lein on any other assets or balance sheet of a parent company. This is called "non-recourse project financing", or special-purpose-vehicle (off-balance sheet) financial for the specific project, i.e. the banks or financiers do not have any recourse beyond seizing your specific solar PV plant assets. Project financiers for utility scale projects with good offtakers may demand at least "limited recourse", i.e. lien on parent company balance sheet in the "construction" phase or for a limited time period, and convert back to just the project-as-lein for the rest of the "operational" phase, post project commissioning.

In the rooftop sector, if you go to banks today and propose this for your rooftop solar, you will get a response that the bank wants to do recourse financing, i.e. they need collateral of more than just the solar PV system (remember you have 30% of equity in it), AND typically a lien on other assets (eg: FDs or financial investments (eg: debt funds) you may have with the bank if you have a long term relationship, or a lien on fixed assets that THEY understand how to sell on the secondary market, i.e. a home etc).

If they can classify this as a loan under a housing-loan category, then they can piggyback on all the great regulations/fund availability for this sector to offer lower interest rates because they have powers under SARFAESI act to seize your home if you default on your payments. Renewable energy has also been classified as a "priority sector" - banks are required to do 40% of their lending to priority sector causes (and since solar PV is a "lower" risk, priority sector lending opportunity, banks should be enthusiastic).

Coming back to housing as an addition recourse collateral for solar PV -- a home (or more precisely the land underneath which is the core of value of a home) cannot walk away, whereas a solar PV plant could be dismantled and disappear! (bankers who lend at 70:30 leverage ratios are VERY risk averse and think of all of these possibilities - and they should). The bank knows how to sell off a home and monetize it; but there are no visible / well-operating secondary markets for used-solar PV systems or system assets (eg: used PV modules, inverters). This suggests an innovation opportunity that if beyond monitoring (of solar PV performance, security cameras etc), escrow accounts (where the EMI slice of the bank comes directly from the escrow account), if a secondary market emerges for solar PV equipment, it will increase the funds flow into solar loans.

All this talk of attaching your home (or real-estate) to the debt contract makes sense if we are talking rooftop solar. For utility scale solar, there is no home to attach to, and therefore, bankers want to attach leins on broader balance sheets of the developer company, or charge higher interest rate if it is a non-recourse off-balance sheet SPV.

Third, the conversion I did above from 14% pre-tax interest rate to 9.8% post-tax assumes a tax rate of 30% and a profitable enterprise. If you have 80% accelerated depreciation, unless you have additional sources of revenue that you mix with the solar PPA inflows, the tax benefit on interest payment (and depreciation) will roll over to future years. This effectively means that you don't get the full 30% discount from pre-tax to post-tax rates. This again implies that (a) you increase the yield of the assets (eg: via operational excellence or technologies like photonic harvesting that IBM is developing) or (b) bundle the earnings / cash flows from other profitable business (eg: petrol bunks, tax accountants, real-estate lease incomes etc) into the financial income statement. While this can be done on a consolidated income statement of a company with multiple businesses, it is harder then to separate out the solar PV project itself onto an off-balance-sheet SPV and finance it separately (since the interest coverage ratios, and cash flows to drive the depreciation / interest tax benefits will disappear).

In summary, we have seen how a solar PV asset procured at good CAPEX (India has the lowest installed CAPEX in the world now), good operating practices, and strong PPA counter-parties to procure power can be the basis for solar finance since it has 20% IRR (for 50kWp+ systems - rooftop or utility scale), and 14-15% IRR for residential small scale systems, once government policy support / tax frameworks are considered. **Such finance can spike up leveraged or equity IRRs (internal rate of return), assuming low capital costs, high leverage ratio (70:30 financing), and long term loans (15 years+, and**

reasonable rate, 10% post-tax rate) making investment in solar attractive **for the developer (high IRR = high RoI, return on investment)**.

Arranging such large upfront finance at a high leverage ratio for a longer term in the context of India today involves some clever financial engineering and negotiation of terms such as recourse / non-recourse, refinancing after 10 years etc. However, the fundamental risk profile of solar PV is low with good operational practices and security of the asset. Extracting high asset yield and monetization is very important, and can magnify the leverage effect in both directions (low yield means poor economics).The government has classified RE as a priority sector lending area as well, which means that a significant amount of domestic capital can be mobilized (in addition to foreign capital). **As the capital costs of solar decline, and** new ways of raising energy yield / manage asset productivity over the long run **improve, the already attractive RoI and IRRs will become better for the savvy first movers in solar PV development in India. This will drive adoption rates of solar PV in India.**

In future articles we shall cover how such mechanisms can come together into business models such as third-party ownership / solar-as-a-service (solar PPA, lease), solar loans, solar securitization, peer-to-peer financing, yield-cos, solar financing for the poor/offgrid (eg: pioneered by Selco) etc.

The reality is more nuanced, and a function of (a) project capital costs (lower CAPEX significantly impacts) (b) project yield, & OPEX (higher yield significantly impacts economics) (c) term of debt (15 year+ loans better for utility scale / medium sized rooftops) (d) debt / equity ratio and debt rates (higher D/E ratios like 70/30 boost up returns further, but D/E will be limited by prudential debt-service-ratio norms).

Specifically, a residential project with high capex, no subsidies, low-medium feed-in-tariffs, low-medium energy yield may not benefit (i.e. neutral) from a leveraged return perspective by taking on debt; although it may be OK on economics from an opportunity costs, i.e. earnings yield perspective (> fixed deposit rates). #1 Rooftops in India

Look at the photograph above that I took from my apartment. First observation: so many roofs, and no solar PV ! Huge market waiting to be addressed. Simple math that if there is a roof (that allows at least 5 kWp or 500 sq ft) for 1 in 100 Indians, given that India has a billion people, we can have 10 million roofs, and 50 GWp of rooftop capacity, just in the residential sector. The commercial sector and industrial sector will have at least equal potential. But we have to address a set of subtle issues to harness this potential. So lets continue our observations on the picture.

Second observation: We see roofs of all shapes and sizes. Third: It is common experience that buildings keep popping up around you and your roof's sun availability can change within 1-2 years! If you are a homeowner, based upon FSI regulations and your personal needs, you may want to expand your home vertically once in a few years. Fourth: unlike western roofs, Indian roofs tend to be flatter (this is good). But, on the bad side, there are all kinds of obstacles and shadowing artifacts on roofs: often the entrance to roofs is via a room like structure, on the top of which there is a water tank. There are open "beam" or "column" structures with steel bars sticking out. In some homes, there is a cell phone tower that sticks upward shadowing both their roof and their neighbors' roofs ! (...and who knows, as operators try to reduce the call-drop problem, we may have more of these!)

Fifth: If you are considering a solar canopy over a parking lot, the building itself may shadow it for part of the day. Sixth: When there are power cuts, a grid tied solar PV system goes offline. Seventh: Cities have a lot more fog / smog / aerosol content, especially in winter months (Delhi is a poster-child of this). Eighth: The dust swept up thanks to traffic and construction tends to land up on solar panels on roofs. Ninth: Bird menace & poop is high in several cities (apartment owners including myself often encage their balconies to protect against unbounded bird pooping effects). In some localities, monkeys or bees pose interesting problems.

All this means that if you have 5.5 kWh/m^2/day raw solar potential available, the ACTUAL production could be as low as 4 kWh/kWp/day, and could be exacerbated by the choices of panels, inverters, maintenance (how often you clean the panels) etc. Lets understand these effects a little more closely.

#2 Shadowing, Dust & Soiling

A c-Si solar module consists of 60-72 solar cells (each solar cell about 8 cm x 8 cm) connected in series. The electric current produced by a solar cell is linearly proportional to the irradiance (i.e. intensity of light) integrated over the entire cell area (and the voltage has a logarithmic relationship to the level of this integrated irradiance). Consider a thin shadow (eg: from a loose steel bar nearby) that covers 10% of the solar cell - this will lead to 10% lower production by that cell.

Now since the 60-72 cells are connected in series, the DC current that can flow through the entire series of cells is limited by this "crying baby" cell which is shadowed! The entire solar module (i.e panel) production drops by 10% even if the other solar cells in the module are uniformly illuminated. Almost all installations in India are on grid-tied string inverters. In this inverter configuration, the performance of an entire string of solar modules is a MIN function of the worst performing solar module (which in turn is dependent upon the performance of the worst cell in any module!). Imbalanced illumination or shadows therefore are an issue. Now it can get worse...

A thicker shadow caused by a more distant shadowing artifact can non-linearly cut output bringing the production of the panel to 20-30% of capacity. Its easy to observe that shadowing may be a function of time-of-day (more shadowing expected in mornings or evenings if you have some clearance, and peak production times are OK). There is a nice YouTube video that illustrates how different patterns of shadow have different performance impacts.

If there is a soiling incident (eg: bird poop or a leaf) that occludes a cell completely, even worse things can happen: the cell goes into reverse bias and dissipates all the power produced by the series of cells (thus heating up and reducing the lifetime of the cell and panel!) in addition to lowering short term performance. Aneesh Nainani explains this effect very well in his Stanford class youtube (warning - a little technical). For a non-technical observer, it is a little non-intuitive to understand that solar panels can actually heat up and degrade faster in the absence of light, as seen by individual cells, accompanied by non-uniformity, i.e. when other cells are illuminated. But the solution is easy: just clean the modules, and make sure you clean it uniformly (pay attention to poorly cleaned patches!).

In the planning phase of installation, a lot of attention is focussed on the sun path diagrams (during the year) and any obstacles that may lead to shadowing. IBM Research work on photonic harvesting can potentially increase the addressible areas where light can be harvested, and shadows cancelled out (even if you do not want to put a solar panel there due to partial shadowing.

Good solar modules also tend to have a number of bypass diodes engineered into them, i.e. it will isolate or bypass the poorly performing column of cells. The more the bypass diodes the better. You have to dig deeper into the solar module specification to find more info on this. Note that a cheap module may have fewer bypass diodes and its performance will reduce significantly with any shadowing. SunPower mc-Si Maxeon modules have bypass capabilities at each cell level. Most Tier 1 pc-Si panel makers tend to have bypass diodes for every 12-20 cells. More the bypass diodes, the better (but costlier the module becomes).

Dust has some counter-intuitive behaviors. Light hitting a dust particle tends to be partially absorbed; but 50-60% of it is scattered (eg: Sahara desert has high albedo - which is why you can see it brightly in pictures taken from space). Some of this scattered light is lost, but a good fraction of scattered light can also enter the module and contribute to production. So, with a thin layer of dust, performance tends to drop by 5% quickly (because of the shadowing/absorption effect), but then the performance drop does not decrease significantly (due to the scattered light absorbed by the panel) unless there is much thicker layer of dust (when it drops rapidly 20-40%).

The relatively flat regime of performance is because of the scattering effects of dust, where a portion of scattered light is absorbed by the panel. In this way, the scattering effect of dust can partially compensate for the shadowing effect of dust! Therefore if you have a thin external shadow on a dusty panel, the dust may actually help the cell get some scattered illumination and not go into reverse bias!

Dust tends to accumulate past late mornings, but sticks on panels because of the dew in the early mornings which affixes the particles. Cleaning should therefore be relatively easy early in the morning by leveraging the existing dew. Cleaning done once a week can avoid the dust thickness from growing into the non-linear regime. Bird poops are best cleaned as soon as possible especially if it occludes a 8 cm x 8 cm solar cell significantly.

Thin film modules (eg: FirstSolar CdTe modules, or Solar Frontier's CIS modules) tend to have larger solar cells (i.e. a few strips of solar cells per module). Remember, we said that the fraction of shadowed (or soiled) cell area compared to the total solar cell area is what matters to first order. While the shape and extent of the shadowing phenomena matters, in general thin film cells, because of their larger area, tend to be more resilient to partial shadowing or soiling, and you get greater energy yield, i.e. kWh/kWp/day of production in such conditions.

Recall that the performance of an entire string of modules is a function of the worst module (or the worst cell in any module!). Almost all installations in India are on string inverters. There is a power electronics solution to alleviate this problem as well, broadly called module level power-electronics (MLPE). In developed countries, increasingly micro-inverters (eg: Enphase) or DC optimizers (eg: SolarEdge, Tigo) are being used in residential, commercial settings to maximize the power output by adding up the power from each module (as opposed to being limited to the Min(module power in a string)). These power electronics innovations are fast dropping in costs, and should become attractive in India for rooftops, especially if they can be used in conjunction with Thin Film modules like Solar Frontier CIS which are resilient to partial shadowing.

#3. Diesel Offset with Solar (and optional storage).

Diesel gensets have low capex, but high opex. They need regular maintainence; and the variable cost of diesel is high. To see this, consider that 1 litre of diesel in India costs about Rs. 45/litre, and can yield about 3 kWh/litre. This implies that the cost-per-kWh of diesel is Rs. 15/kWh (which is 2-3 times the cost of utility power). This is the best-case scenario: diesel genset efficiency is much lower, and cost 2-3 times more, when it runs well below its peak capacity (in my apartment we have a 160 kVA DG set, and loads fluctuate between 10-60 kVA during powercuts). Diesel gensets are essentially providing a distributed peaking generator service for the wealthy and commercial establishments because the local utility (or discom) is financially cash strapped when demand exceeds supply and cannot buy the approximately Rs. 5-6/kWh cost on spot markets (and add in about Rs. 1-2/kWh for network costs).

Rooftop solar LCOE is about Rs. 7-8/kWh (depending upon the term of financing). Unfortunately, the way grid-tied solar PV inverters work is by disconnecting from the grid when it does not see a "clock" or "signal" from the grid for safety reasons (we don't want solar-generated energy electrocuting a repair worker somewhere on the distribution grid!). Therefore, even if the sun is shining, and there is a power cut, solar PV cannot offset diesel generation if used naively.

There is however, an interesting mode, where once the PV system is disconnected; the building LT panel switches over to the DG (diesel genset) system, the DG system can generate a 60 Hz clock. An appropriately configured LT panel, and minimally sized DG system can then allow solar PV to restart and inject into the local grid (up to the level of load on the grid). Therefore, especially in apartment complexes (with large DG sets) and office/mall buildings, there is good potential to offset diesel consumption during daytime power cuts with solar PV (even without battery). In IBM buildings, we estimate this to be about 10% of total units since DG sets run at full blast (1.6 MVA per building!) when there is a power cut; and during summers, power cuts are mostly concentrated in the day time.

Another (costlier) setup involves a hybrid inverter with a energy storage system to provide the grid backup via the storage system; and the solar PV charges the energy storage on the DC side. In this article we cover how such mechanisms can come together into business models such as third-party ownership / solar-as-a-service (solar PPA, lease), solar loans, solar securitization, peer-to-peer financing, yield-cos, solar financing for the poor/offgrid. We also briefly cover other possibilities (of e-Commerce driving solar).

The broader structure of the solar market (from upstream to downstream) involves: (a) solar technology players & equipment makers (including Si- or thin film technology providers, module makers, inverter & power electronics companies), (b) solar engineering, procurement and construction (EPC) companies and solar installers (and operations service providers), (c) solar financiers and financial intermediaries, and (d) system owners (end-user owners or third party owners).

Like markets around the world, the Indian market has the utility-scale segment, commercial & industrial segment (C&I), residential segment and off-grid segment. Lets examine each in turn.

Utility scale solar is typically ground-mounted solar plants owned and operated by an Independent Power Producer (IPP). The overall programmatic sponsor is typically the central government (via the Jawaharlal Nehru National Solar Mission (JNNSM) with NTPC being an offtaker) or state (via state level auctions and offtaker is the utility). Budgetary allocations are legislated or firmly set aside. The financial counter-party may be directly or indirectly done by the central government entity (to reduce counter-party risks of an local utility with shaky finances), and the technical offtake is done by the utility. Awards are being done via an electronically conducted reverse auction method, and are a fixed price per kWh over 25 years. The headline news about Rs. 4.63/unit or Rs. 4.34/kWh usually refers to this contracted tariff rate won by the bidder.

In the future, it is conceivable that the IPP model may evolve into include some government (minority) stake in project equity. A BOOT model (i.e. build-own-operate-transfer, i.e. transfer the asset at the end of the term to the government which can capture the long term residual value). Some multilateral agencies may participate via mezzanine debt or via loan guarantees. Ideas like dollar-tariffs or a centrally managed hedging fund have been proposed.

Repowering of plants (i.e. replacement of old panels with newer technology) is being allowed; and excess generation via solar yield-improvement schemes up to certain evacuation limits is being accepted. Solar parks are organized facilities where developers may build the farms. These solar parks have land, evacuation facilities (to the nearest transmission grid) and other services arranged, and are often co-financed at low capital costs by multi-lateral infrastructure ecosystem financiers like world bank/IFC, KfW, JICA (Japan), ADB, USAID etc).

The Commercial & Industrial (C&I) segment is not just rooftop solar, but also "open-access" solar where the actual solar plant (of at least 1MW) may be in a solar park or a remote facility several hundreds of km away (typically in the same state, but can be inter-state as well), organized as captive, group-captive or lease-model with a "wheeling and banking" arrangement facilitated by the utility. The end-user contracts a power purchase agreement (PPA) with the solar PV developer to off-take a minimum amount of units each month (and up to the maximum produced by the plant and banked). Excess needs beyond this is met by the state ESCOM tariff rate. In Karnataka given the policy of the state regulator to waive the cross-subsidy surcharge (CSS) on solar PV, we are seeing the PPA rates lower than the corresponding commercial tariffs leading to a significant defection of commercial customers going towards solar. Government or a private entity could also aggregate the rooftop spaces on their facility and award a project development contract for rooftop solar.

A captive model in open-access solar (i.e. where the solar PV plant is remote) is where the project equity majority stake is held by the end-user (some IT companies in Karnataka and industrial companies in Tamilnadu and Gujarat are examples of those who have done this model). The developer also typically has a minority stake, and usually there is a high leverage debt arrangement (eg: 70:30 Debt:Equity) over 10 years+. All the output of the farm is earmarked and offset against the electricity meter bills of the end-user. The sizing of the plant is done to be well within the expected consumption profile of the customer. Excess generation can be "banked", i.e. credited with the utility and used within a year (i.e. offset against the subsequent bills). As a new emerging trend, a real estate developer could also be the owner/promoter/developer of the solar farm and sell the energy to their lessee tenants. Embassy Energy is one such example of a real-estate developer where the company plans to sell the output of their 100 MWp plants to their large tenants in their STPIs, SEZ and industrial zones. Typical buildings in business parks may have about 2 MW of connected loads.

A "group captive" model is a variant where a group of end users hold joint equity stakes, and have minimum off-take commitments, and appropriate automatic settlement mechanisms for the excess solar generation and use beyond the minimum commitments. Again the debt-equity ratio is high in the project finance structure.

In residential or small-scale commercial solar, the simplest setup is where the end-user buys the PV system, and has a maintenance contract with the solar installer. The local state may have a policy such as net metering and feed in tariff: different states and market segments have different levels of financial attractiveness. We have reviewed the economics and policy aspects thoroughly in the rooftop PV series (part 1, part 2 and part 3). This is an evolving picture as different state regulators update or revise their regular electricity tariffs or the solar PV policies. Note that it is the interplay between the regular electricity tariff and the prevalent local solar PV policy when the solar PV system is commissioned that matters for economics.

The user may pay up full cash for the system, or may need financing, i.e. solar loans. While MNRE has notified several banks to offer solar loans, it is common experience that the local bank manager is not very aware or sophisticated about solar PV loans and just offer personal loans at higher interest rates for short terms.

Financial loan originators (eg: Oorjan) help arrange financing at lower interest rates and longer terms (than personal finance loans) from banks or infrastructure financing sources (eg: IDBI etc). The interest rate may be not too far off from your home loan rates with a good financial intermediary. Collateral required in such financing could very from unsecured (for small loans) to secured by the solar PV system alone (non-recourse financing) or may require this to be linked or rolled into the housing loan (i.e. home as collateral in addition to the system). The counter-party is usually the consumer; but if there is an escrow account and gross-metering, it may be possible to directly deduct the interest payment from the PPA payment from the ESCOM/utility. Some degree of production monitoring and data analysis is presented to the bank to help ongoing credit risk analysis. Some insurance for larger PV systems may also be necessary (and could be waived if there is adequate security in the home or apartment complex).

The next model is third party ownership (TPO) (typically for residential, small or medium commercial) where the solar PV system is owner by a third party, but the roof space is that of the end user (or their land lord). There is an operating lease or power purchase agreement (PPA) signed between the TPO and the end user. The end user in turn gets a PPA from the utility. Sometimes these two PPAs may be merged into one agreement between the ESCOM (utility), the third party owner (TPO) and the end-user. An escrow account may be set up in this case to reduce credit risks, and the payments to the TPO may go directly as a fraction from the ESCOM PPA payments to the end user.

The reason this may be attractive is that solar PV is now provided "as-a-service" (i.e. "solar-as-a-service" or "solar lease") similar to the utility electricity service or cloud VM/web services without upfront investment (i.e. zero-down) or ownership by the end user. Sometimes the term "operating lease" is used to indicate a fixed monthly charge to the user, whereas a PPA implies that the user pays for the actual solar production at a charge usually linked to their tariffs (if there is net metering). SolarTown is one example of such a PPA provider in India (amongst other options it provides)

The Third party Owner (TPO) can avail of accelerated depreciation (AD) benefits if they have enough other revenue as discussed in prior articles (eg: policy article and finance part 1 article). Sometimes, if the TPO is not just an installer / owner, but also a financing entity (eg: a non-banking financial institution (NBFC)), it can raise capital from private financing partners (eg: banks, a syndicate of banks, insurance companies, pension funds or other institutional investors as discussed in part 2 of this series), public bond market (eg: solar bonds, green bonds, climate bonds etc), or aggregate a portfolio of solar PPAs and securitize it and sell it to the public markets directly.

This last option, i.e. aggregation of a portfolio of operating / yielding solar PPAs and creating a financial security against it is called "solar securitization". Both solar bonds and securities are similar in that they are offered on public (or private) markets, and have to be rated by bond rating agencies. Someone has to be held responsible for collection of the revenues and administering the distribution to security holders. A key difference between solar bonds and solar securities is that the solar bonds may have a lien on the corporate entity; whereas solar securities depend on the pass through of the cash flows from individual PPAs.

Like other securitization (eg: home/auto loan receivables etc), there can be tranches which are rated differently by rating agencies. SolarCity in the USA is an example of such a player which has raised finance from all these mechanisms. Solar securitization is perhaps more appropriate to the rooftop sector (but could also be applicable to a collection of medium-sized ground mounted farms) and is therefore new / not very prevalent in India yet. The important aspect is that rating agencies should be able to assess the veracity of the cash flows (and any impediments) and the robustness of the diversification offered by the aggregation (eg: the same ESCOM defaulting could affect all solar cash flows securitized from a single state).

{As an aside: In the USA, since there are other tax subsidies (eg: Investment Tax Credit), these are packaged and passed through to tax equity investors who have an appetite to shelter their profits from tax (usually large financial institutions and some players like Google). This mechanism is called tax equity financing, but is not relevant for India since there are no tax subsidies in India, and it is not easy to package and sell any such subsidy to third parties that offer financing. }

Peer-to-peer solar financing could be used for either the debt or equity part of the solar PV plant financing. However, the general idea is to pool peer-to-peer finance into a debt pool similar to securitization. In the India market, there are a lot of investor protections given past scams in chit fund and other debt markets. Peer to peer finance has been limited to single projects where the project details are shared w/ the investor (i.e. pure match making) and the investor has to do due diligence prior to financing. There are limited mechanisms to collect payments when the counterparty (esp consumer) stops paying, and such "peer" investors (High Net-worth Individuals (HNIs) or Non-resident Indians (NRIs)) may not have the time or resources to pursue recoveries. This financing method may be more appropriate when there are escrow accounts (where payments come in from a more reliable source directly) and specific projects by third party owners (TPOs) can be matched to specific peer investors. To make sense the interest rates demanded by peer-investors will be higher than that of banks (or what they could get from alternative similar-risk investments), and in an environment where bank based debt capital is hard to come by. SolarCity, a distributed solar promoter in the US and Mosaic, another US company have experimented with this peer-to-peer mechanism, which is still in its infancy / maturity even in global markets.

Innovative & socially focused service companies like SELCO have gone a step further to customize the payment terms for off-grid solar PV to match the bursty and opportunistic cash flows of the poor. In this sense of accomodating variable cash flows, they have some equity-like characteristics. SELCO offers a solution combining solar PV, batteries and DC appliances (fans, lights etc) and an operations & maintenance (O&M) contract. The interest rates are correspondingly higher like micro-finance entities etc. The solar pump and related microgrid business is another one that is seeing a lot of innovation focus. Again the key business question to be answered for financing solar pumps and microgrids is who pays and how (government contract or individual farmer) which determines counter-party credit risk and cash flow risk.

One mechanism that achieved a lot of popularity recently (and a spectacular fall) was the idea of a "yieldco". This business design stems from a simple observation we examined in project finance (part 2) : there is a lot of risk in the solar project development phase, but once the solar PV plant is established with a long term PPA and a credit-worthy offtaker as counterparty, there is far lower risk to cash flows. As the sun rises and sets with 100% reliability, we can work out the average production (accounting for average cloudiness and equipment performance reliability), and average conversion of kWh produced to yielding consistent and predictable cash flows as per the contracted PPA. The idea is therefore to separate out the development phase from the operational (or "yield") phase into two different entities: a development company ("DevCo") and a financal holding or yield company ("YieldCo").

The laws of finance dictate that when cash flows are predictable and low risk, they can be financed by lower cost of capital. Yieldcos finance the low-risk cash flows with two sources of low-cost capital: low-cost debt, and possibly low-cost equity (organized similar to real-estate trusts) where the cash flows to equity are simply passed through as dividends without being retained in the entity. With predictable cash flows to both the debt and equity portions, the cost of capital can theoretically be low. The development company DevCo focuses on acquiring a good pipeline of high quality projects (at reasonable costs), and once developed they can be "dropped down" to the YieldCo at lower capital costs, i.e. at higher price realizations. When some of the yieldCos were listed on the public equity markets, their pricing reflected very low dividend yields. (Note that as risk-free rates rise, the cost of capital of both the equity (dividend) and debt part of the yield co rises.)

{As an aside, SunEdison global, a DevCo with controlling stakes in two yieldCos, which recently filed for chapter 11 (their India unit is not part of the bankruptcy) appears to have extended the "low-risk" cash flow idea beyond utility-scale solar to utility-scale wind, C&I solar, residential solar and currency risks. They also appear to have paid a high premium for a development pipeline when they made acquisitions. Shareholders of both the yieldCo and devCo marked down share prices, i.e. raised the equity cost of capital, and the devCo projects could not be "dropped down" at high price markups, and had to be held in the DevCo (burning through the working capital "warehouses") or sold-off to third parties to regenerate equity capital. Apparently this didn't happen fast enough while they committed to more projects, and the debt service burden overwhelmed the DevCo. Abengoa in Spain apparently took on complex projects (which did not fit the low risk profile) in its yieldCo. NRG, a US company which pioneered this YieldCo mechanism, also has seen mixed results. Some have blamed the fickleness of public markets and its ability to either herd or run for the exits as a factor. As a result there is a chill over this financing mechanism which is somewhat unfortunate. Another lesson here is that solar securitization may have been more appropriate for an aggregate of residential or C&I cash flows than a yieldCo, where the risk is rated and priced appropriately. }

This article does not discuss a variety of other solar players in India in the EPC segment, or innovative technology / product companies (some notable smaller product companies in India include PlaySolar and iGrenEnergi). Since solar PV systems are relatively simple, we may also see a potential unbundling of "EPC" where the "P" or "procurement" piece could be done via specialized e-Commerce retailing portals or even flipkart / amazon / snapdeal which would provide comparison shopping and price-quality information and "reliable" / certified solar PV systems online. Local brick-and-mortar retailers like Tata Chroma could also provide such purchase/install options. Just like we purchase white goods like AC or fridges today, a home or business owner could then purchase the solar PV system online and have a local installer to provide a standard installation, and perhaps ongoing operational support. Financing options could become unbundled as well. This "Dell" like on-line / mobile-based customized computer sales model for solar PV is likely to happen with the market developing further; and the solar PV bundles becoming more standardized and predictable quality / performance.

As we have discussed in prior articles, solar economics becomes increasingly viable with the dropping CAPEX, lower interest rates, longer term financing, lower risk offtakers / escrow accounts etc. With these business models above, we should expect a sharp and continued rise in solar deployment in all sectors in India. It is just a matter of time, and if the solar costs continue to drop, and fueled by business model innovation, rapid adoption can happen faster than we think.