Innovation towards Powering Low-income Rural Homes leveraging ICT

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Dismal State of Power in low-income Rural homes

- 50 million Indian homes not connected to electrical grid
- Another 50 million get power for less than 12 hours a day

- Primary reason
  - can not afford power, even at subsidised rates
  - Utilities lose money in supplying to these homes
  - No reason to supply 24 x 7 power

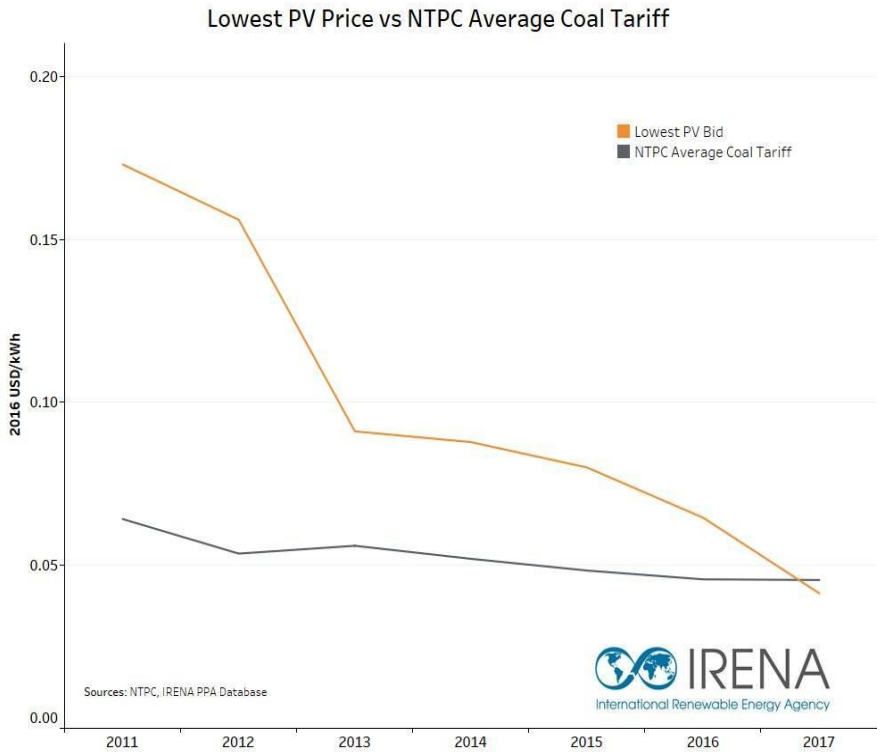
- Requires disruptive Innovation

$1 = ₹64

Three emerging technologies combine

- Disruptive Innovation combines them to solve this vexed problem
  - Falling Solar PV prices ($0.25 per Wp) result in $0.04 per kWh
    - Can be used on roof-tops (no T&D losses)
      - But solar would require expensive storage
      - AC to DC and DC to AC converters will amount to 45% losses

Interest rate	10%
solar PV $ costs per W	0.25
Solar Life (years)	25
Solar $ per year per W	0.028
BoS $ costs per W	0.15
BOS Life (years)	10
BOS $ per year per W	0.024
Total $ cost per kW	51.954
solar insolance (hours per yr)	1500
losses	10%
$ Cost per kWh	0.038



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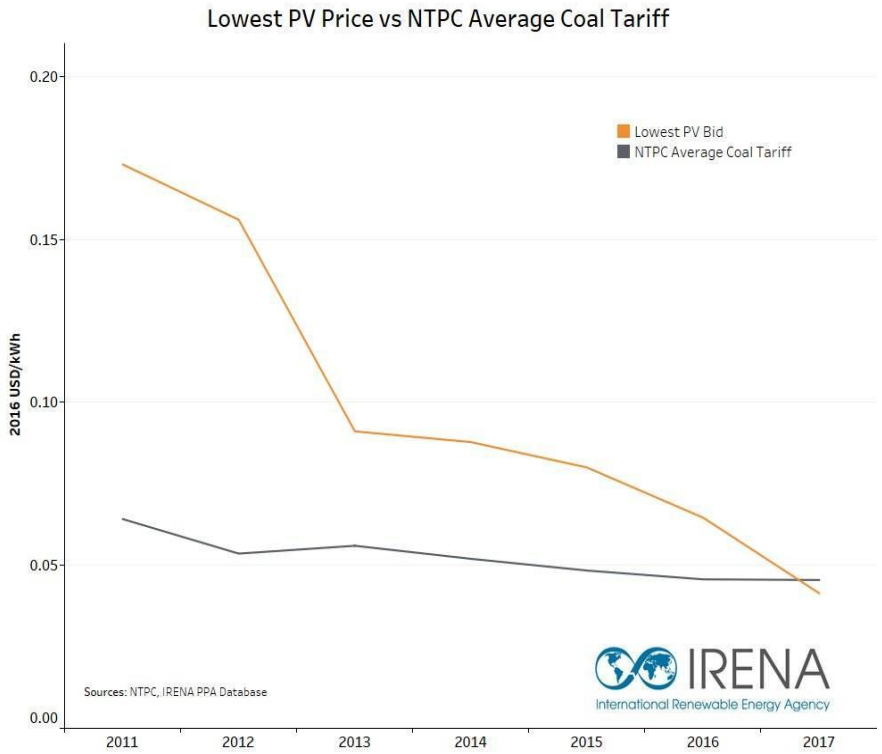
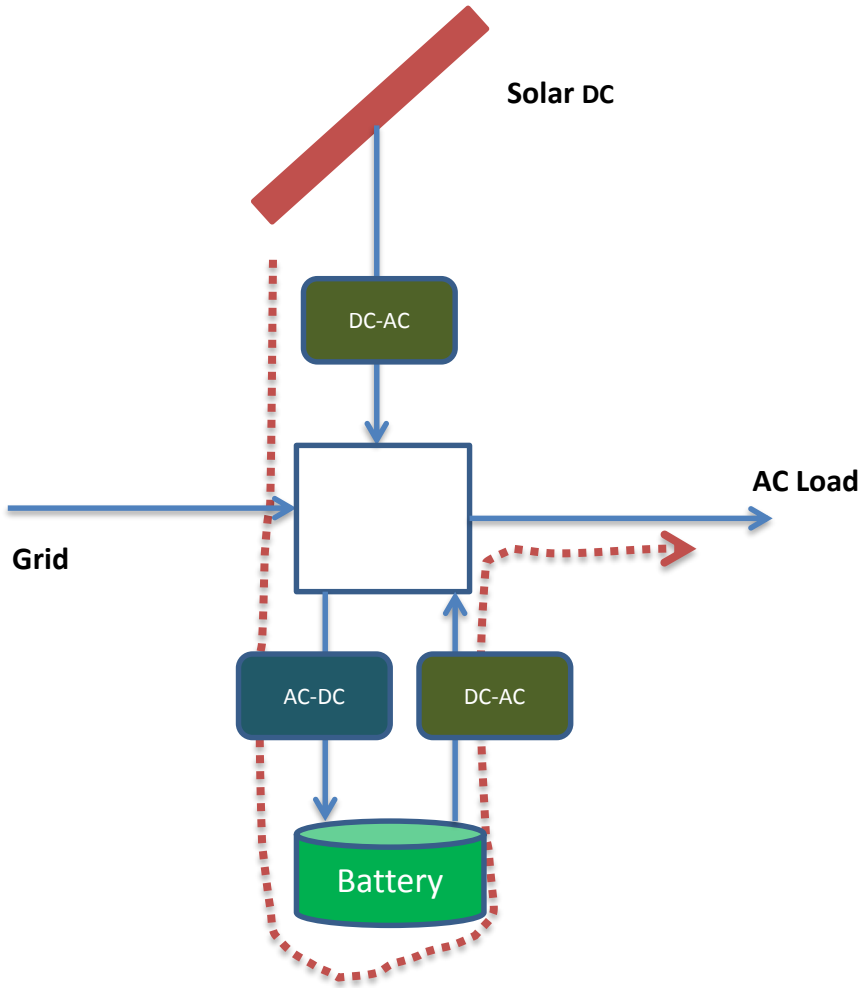
      - AC to DC and DC to AC converters will amount to 45% losses
  - Need Solar-DC will avoid losses
    - But storage will push costs to $0.09 per unit
      - Too high for such customers
  - IoT will help bring in affordability



Decentralised Solar Power at Homes



- Solar PV gives DC Power
  - But load is AC
  - Needs a DC-AC converter
- Now if we add a battery
  - Battery stores only DC
    - Require an AC-DC converter for charging
    - Require a DC-AC converter during discharging
- For *low power (say 100W)*, each converter can have 10 to 15% loss
  - Solar with battery may have up to 45% loss + battery loss

And it gets Worse

- As one realises that home-loads have been slowly moving towards DC

Fans	AC fan	BLDC fan
At full Speed	72W	30W
At speed 1	60W	9W
Lighting	**CFL Tube light**	**LED tube**
At Max. Intensity	36W	15W
At Lowest Intensity	NA	4W

Volume prices similar for fans

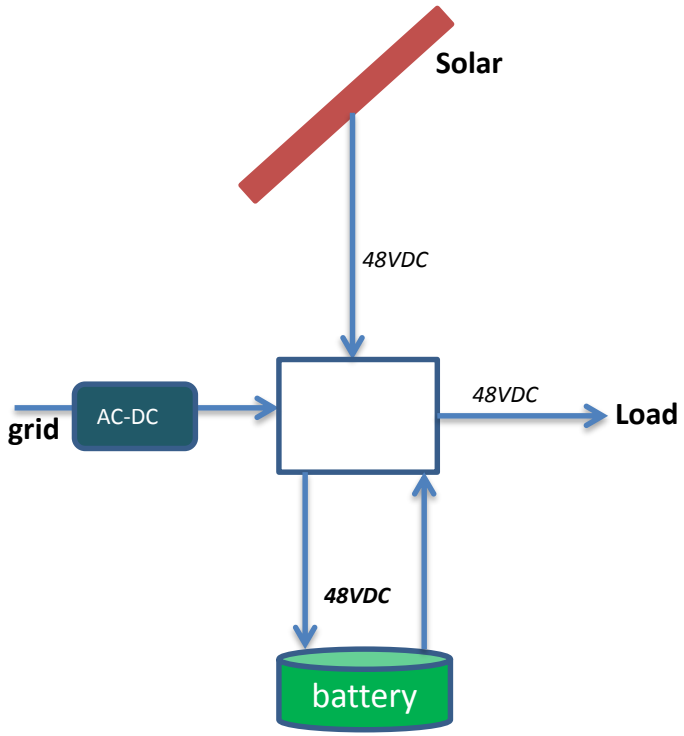
LED tube life much longer (DC powering enhances reliability)

- All Electronics devices work on low-voltage DC
  - TV (LED/LCD), laptops. Cell-phones, speaker-phones, tablets, speakers
    - AC to DC conversion has losses from 20% to 50% in each device

- Even the refrigerators, air-conditioners, washing machines are now using BLDC or SR motors

- DC-powered DC-appliances are energy-efficient
  - Consumption down by 50%

Are we ready to take a leap and move to Solar-DC



- DC Micro-grid connecting
  - Solar Panel
  - Battery
  - DC Appliances
- Highly efficient usage of Power
  - Low-power from grid alone converted from AC-DC
- 48V DC chosen due to
  - Safety considerations
  - Lower cable losses compared to 12V/24V DC systems
- But design non-trivial
  - Solar MPPT voltage varies
  - Battery needs independent charge voltage
  - Load is at some fixed voltage
  - DC-DC converters will add similar losses

IITM designed Solar-DC Inverterless

125W panels
- Upto 500W possible

Designed as an expandable product, still keeping losses low

230V AC

125W to 500W 48V DC (and possibly 150W uninterrupted AC) Power with BLE prepaid recharge

Monitored using Bluetooth (moving to GPRS)

Special 1 kWh VRLA battery with 1600 cycles for 50% DoD
- Up to 5 kWh possible

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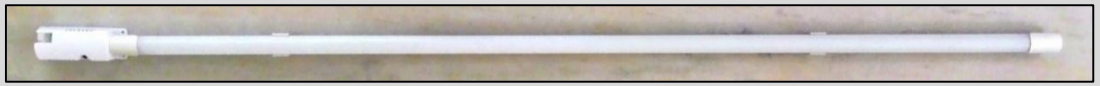
And worked with start-ups to build Appliances

LED Bulb
- 5W instead of 30W bulb

Cell phone Charger/Socket
- DC charger with USB port

BLDC Fan
- 30W instead of 72W AC fan
- 9W at lowest speed



LED Tube light
- 15W - dimmable to 4W, instead of 36W fluorescent tube

Remote Control for Fan & Tube light
- ON/OFF and for dimming

Cost: ₹20000 for 125W SP + 1 kWh Battery+ appliances

Energy-efficient DC appliances being expanded

DC Desert Cooler

- Consumes 120W instead of 180W AC cooler

DC Mixers

- Consumes 150W, whereas AC Mixers consume 350W

DC-powered Colour TV

- Consumes 30W along with set-top box

Butter-churner and atta-chakki, sewing machines, roti-machines

- getting ready

Refrigerator, charkha and Stove

- Still experimental

Deployment in 15000 homes

- Electrified 4000 off-grid homes in Jodhpur and Jaisalmer districts of Rajasthan
  - Tough terrain, no road connectivity, sandstorms, lack of local resources
- 7500 homes in Assam being taken up in hills
  - 12000 more homes being take up
- Grid-connected installations in states of Orissa, Karnataka, Tamil Nadu, Telangana, Andhra
  - Where power cuts > 8 hours /day




Changing lives in deserts

IEEE awards solar-DC as 2017 Technology of the year in Service of Society

Villagers thrilled

- *"Apne Vidyarthiyon ko ghar ka kaam dene laga hu. Khush hu ki is baar garmiyon mein bhi bachhe mann laga kar padhai karenge."* *[now I give my students home-work. Happy that even in summer they will now be able to study]*

  - Masterji

- *"Sab ko utshah se apne ghar ka Solar system dikhata hu ji, hamare ghar mein bhi pankha, light aur remote hai"* *[show my solar system to everyone at home. Have fan, light and remote]*

  - Dunga Ram

- feedback: https://youtu.be/NF6EgdRsBXk

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Small AC / DC Home Power Costs

Device	Numbers deployed	Operation hrs/ day
Tubelights	2	6
Fans	2	12
Bulbs	2	10
Phones	1	4
TV	1	10

Cost / day includes depreciation and interest for solar panel and battery assuming grid costs of ₹5 per unit

	AC Home		DC Home	
	Energy/ day kWh	Cost per day ₹	Energy / day kWh	Cost per day ₹
AC Grid + 0 LS	3.27	16.3	1.29	6.45
AC +Battery + Solar + 4h LS	3.75	28.9	1.35	7.3
off-grid + Battery + Solar	4.9	50.6	1.33	12.6

Off-grid home power-costs with solar-DC (₹12.6 per day) less than the cost of on-grid AC homes with no power-cuts (₹16.3 per day)

Per unit costs of electricity and affordability

  - Solar through battery $0.16 per unit (25% time – day time)
  - Grid costs: $0.08 per unit (50% of time – evenings and nights)
  - Solar-DC costs $0.04 (25% of time – when sun and grid not available)
- Total is $0.09 per unit
  - Load reduced to 60% by using DC-powered DC appliances
  - But **cooking** needs to move from bio-mass (severely impacts health) to electricity doubling electricity usage
- Not affordable to bottom one third of homes
  - Would need $0.05 per unit…

ICT now steps in

- As nations go more and more with renewables
  - and as power output from renewables need storage, and storage is expensive
- Possible to use distributed storage at homes for grid balance
  - Feeding power at low cost when grid is surplus
  - Drawing power from home storage when grid is deficit at higher costs
- While grid balances, customer can gain by deploying storage
  - will need communications (Internet of things) between grid and home-storage
    - Wireless communication reaches each rural home today
  - Possible to do this such that cost of power for a home goes below $0.05 per unit

To Conclude

  - *Mobiles and Internet have reached most homes, even ones without electricity*
  - *Time has come that ICT enables those who have been left behind in all kinds of ways: health, education, energy, agriculture, rural industry*
- Necessary that ICT innovation combines with other Innovations

- Power to a rural low-income home has been a vexed problem for long
  - Falling Roof-top Solar and battery prices give us hope
  - But would need DC power-lines at homes to bring the cost down
  - And storage costs would be brought down by sharing it with rural homes and grid (enabling renewables to grow)
    - ICT will be the key enabler for this