Green Homes, Green Building and Green Transport

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TOWARDS GREEN HOMES

Power for Indian Homes: A dilemma

- 50 million homes not connected to grid
- About 100 million homes have load-shedding between 4 hours a day to 16 hours a day
- 50% of Indian homes can not afford power even at subsidized rate of ₹5 per unit
  - At this tariff all DISCOMS lose money

$1 = ₹66

In first week of December 2015

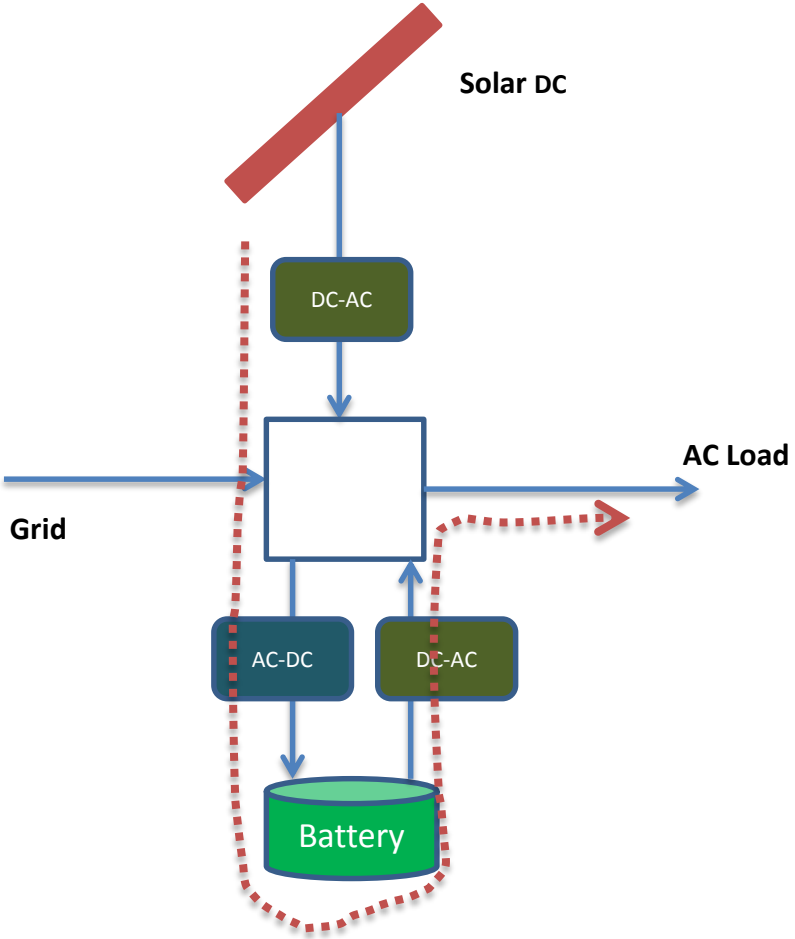
When whole of IITM had no power for 75 hours

- Even 1 MW solar plant at IITM failed to provide any power

– There was one home which continued to have lights and fans and cell-phone / lap-top charger
  - 125W solar panel + 1 kWh battery (50% can be used)
  - Two tube-lights were used regularly + bulb and fan occasionally + laptop charged / discharged fully 15 times + cell phone charging
  - Fails to add up

– Solar DC Inverterless
  - Full DC wiring, all Loads DC, solar and battery connected on DC line, input grid power converted to DC

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 a AC-DC converter for charging
    - Require a DC-AC converter during discharging
- For low power, 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-load is 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

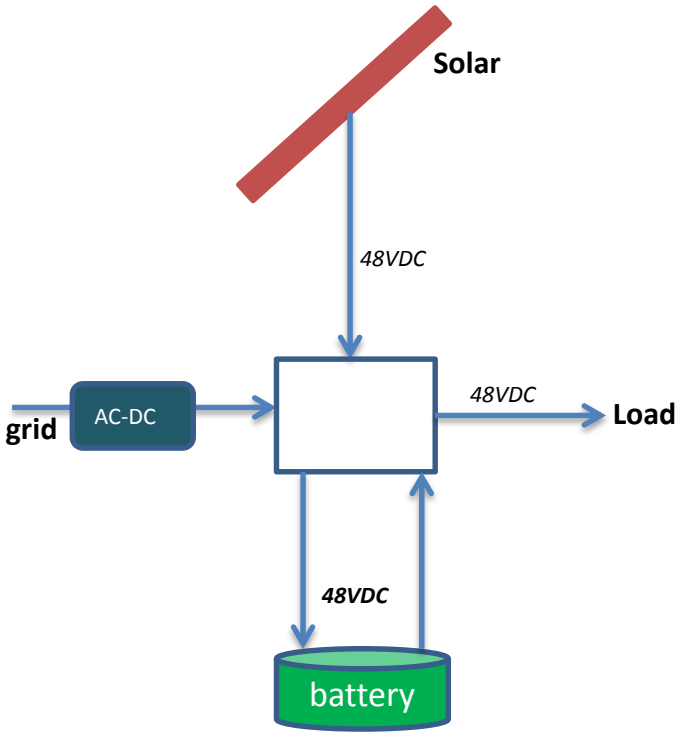
LED tube life much longer (DC powering enhances reliability)

- 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 machine in future will be BLDC motors

- Use of DC-powered and energy-efficient devices
  - Consumption down by 50%

Move to Solar-DC at Home Premises



- Home Micro-grid connecting
  - Solar Panel
  - Battery
  - DC Appliances
- Highly efficient usage of Power
  - Low-power from grid alone converted from AC-DC (Designed to have minimal losses)
- 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

Solar-DC Inverterless

125W panels
- Upto 500W possible

Designed as an expandable product, still keeping losses low

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

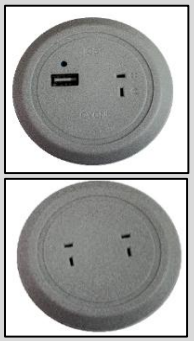
230V AC

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

Monitored using Bluetooth

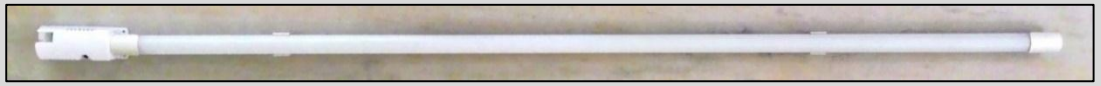
Appliances

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

$1 = ₹66

New Products

DC-powered 19” Colour TV

- Consumes 30W along with set-top box at 48V DC

Refrigerator and Stove

- Still experimental

DC Desert Cooler

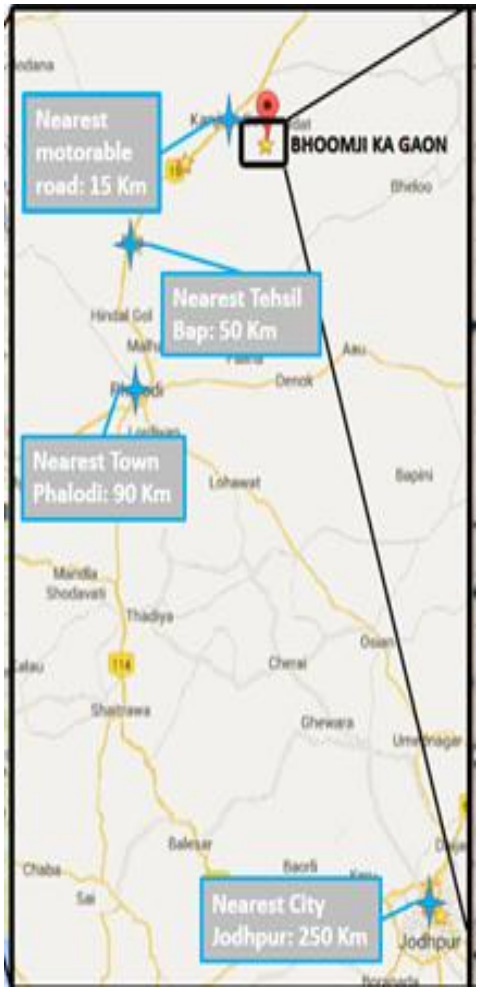
- Consumes 80W instead of 180W AC cooler

DC Mixer

- Consumes 150W, whereas AC Mixers consume 350W

Deployment in Rajasthan

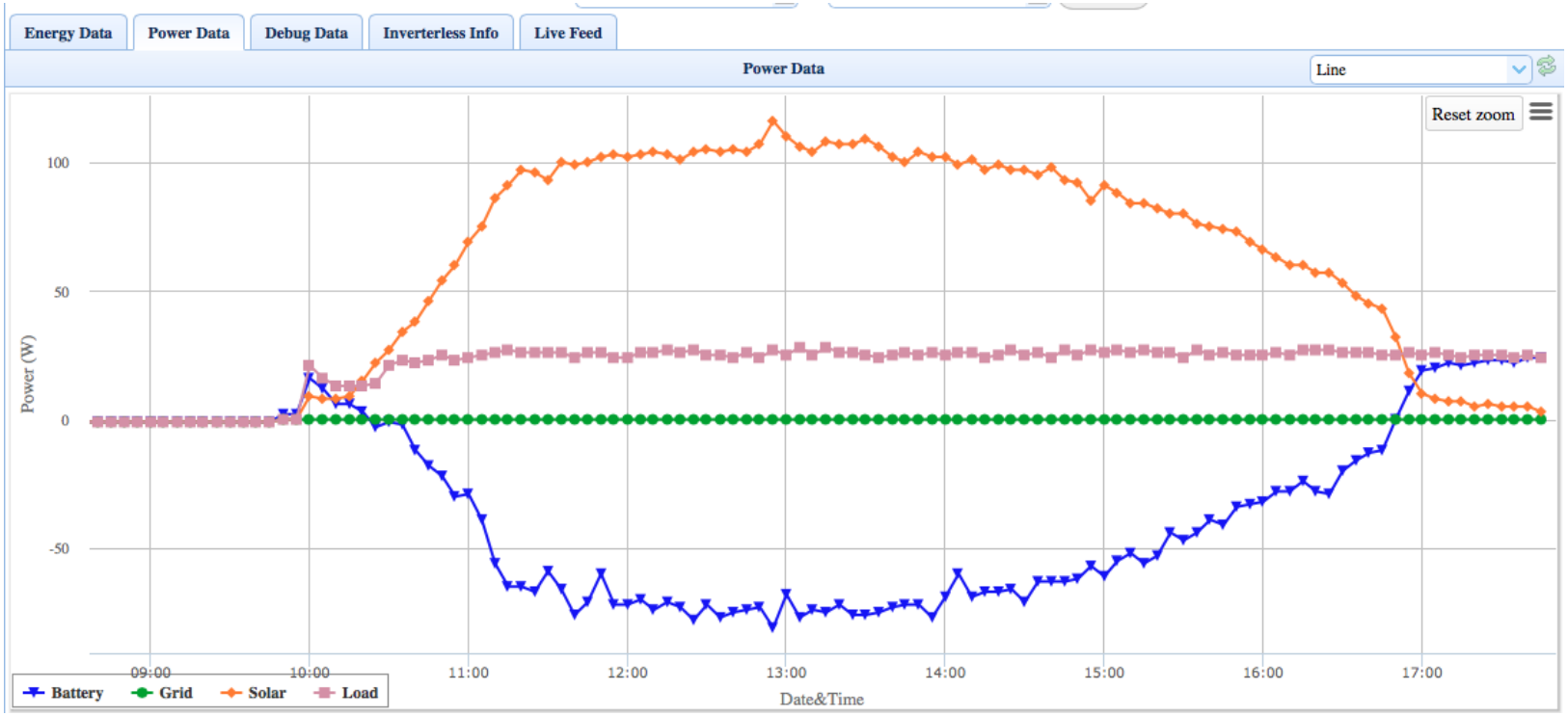
- Electrifying 4000 off-grid homes with support from Ministry of Power (Government of India), Rural Electrification Corporation (REC), and Jodhpur Vidyut Vitran Nigam Ltd (JDVVNL)



- Deployment started with Bhoom Ji ka Gaon, December 2015: tough terrain, no road connectivity, sandstorms, lack of local resources

A home at Bap, Rajasthan

- Remote Monitoring performance through Bluetooth
  - Paramount in design tuning



Users Response

- *"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

Motivation for going Solar Inverterless

- It is a Solar + power back-up, but far more efficient
  - as 100 Watts DC
    - Can support 3 lights + 2 fans + cell-phone charging
    - Or 3 lights + 1 fan + TV (24” LED/LCD) + cell-phone charging
  - Solar Panel and Batteries have to be appropriately sized
    - Devices can be added as required

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
off-grid + Battery + Solar	4.9	50.6	1.33	12.6
AC +Battery + Solar + 4h LS	3.75	28.9	1.35	7.3

Off-grid home power-costs with solar-DC (₹12.3 per day) less than the cost of on-grid AC homes with no power-cuts (₹16.3 per day)

$1 = ₹66

Even for grid-connected home

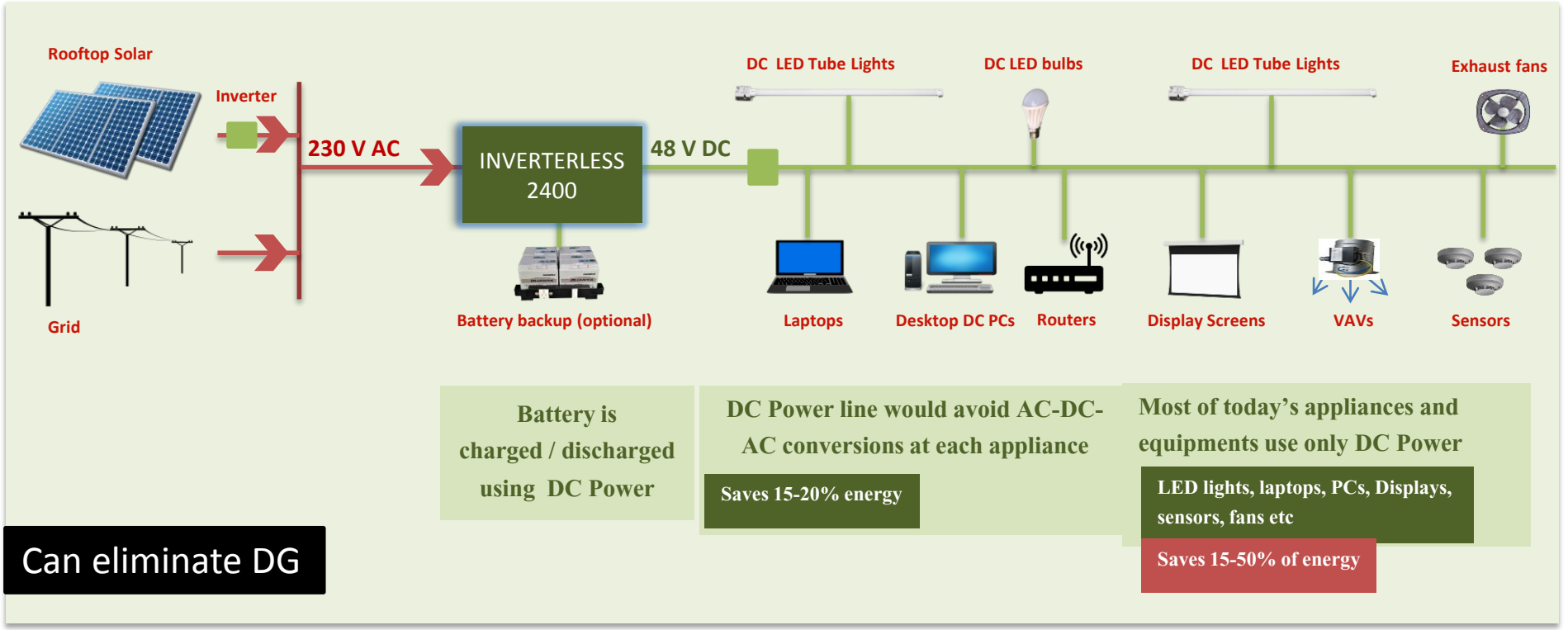
- Solar-DC Inverterless + DC power line at home + DC appliances offer huge savings
- Further, 500W solar power with DC appliances can take care of most essential loads in middle class homes
  - Except washing machines, mixers / grinders, air-conditioners
  - Small power drawn from grid: reduces power-bill
  - 240M homes: average 500W solar (50 sqft), will produce nearly
    - 240M x 0.5 kw x 1600 solar hours a year = 190,000 GWh per year
    - Close to total Domestic consumption in a year
- India can become the most green nation

GREEN BUILDING

Buildings in India

- Depends on Diesel Generator for 24 x 7 power
  - With power cuts ranging from an hour or 6 hours
    - More in smaller towns
  - Expensive (4 times grid power) and polluting
- Building Loads
  - Lights, Appliances (homes and offices), electronics, exhaust fans, cooling load, lift and water pumps
  - Appliances and electronics are quickly becoming all DC loads
    - will benefit from DC power-lines within buildings

Powering Appliances in Buildings



APPLICATIONS:


Apartments

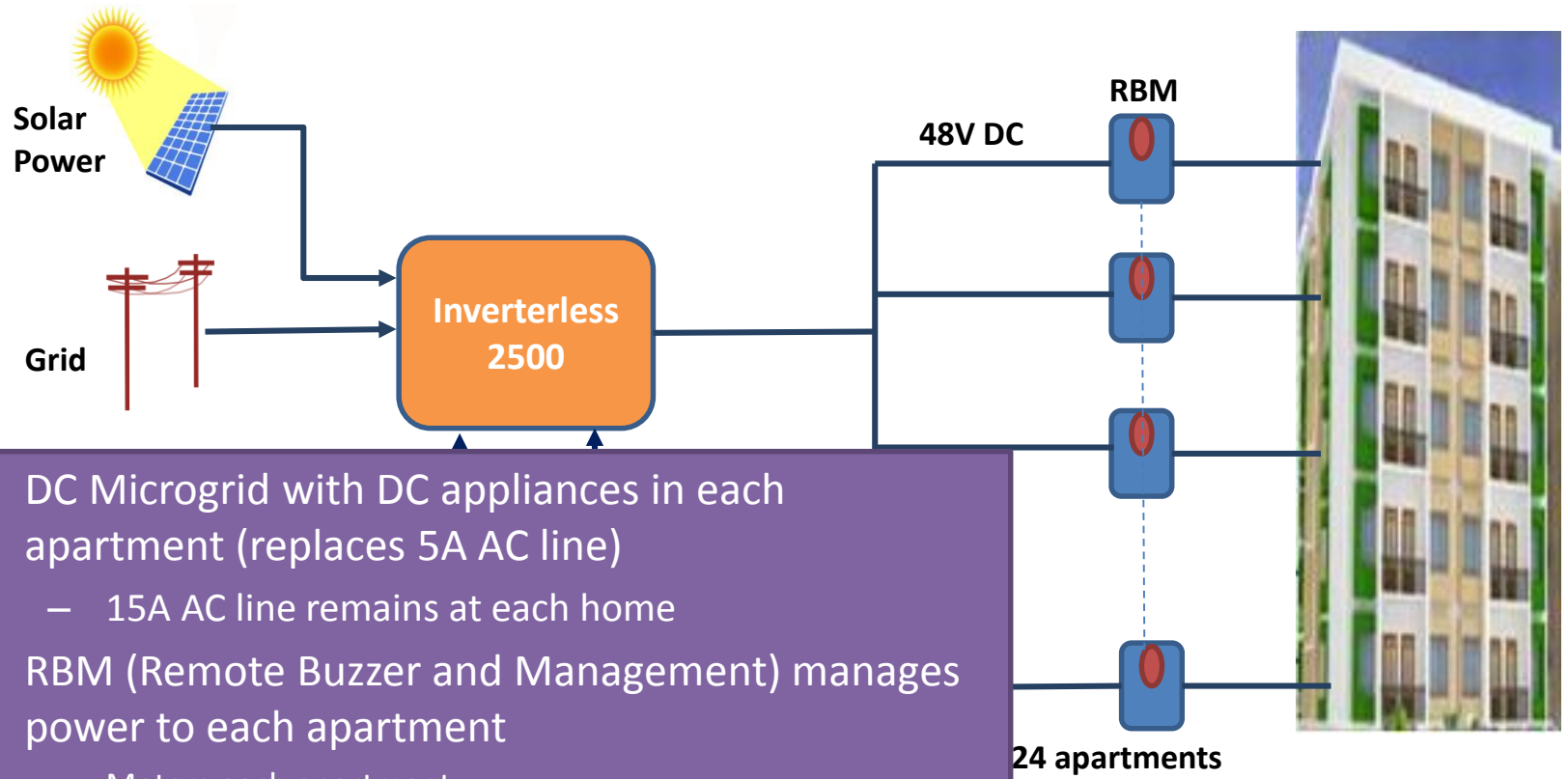

Offices


Hospitals


Commercial Complex


Educational Institutes

Exapmple: Solar-DC micro-grid to 12/24 Home Apartment Complex

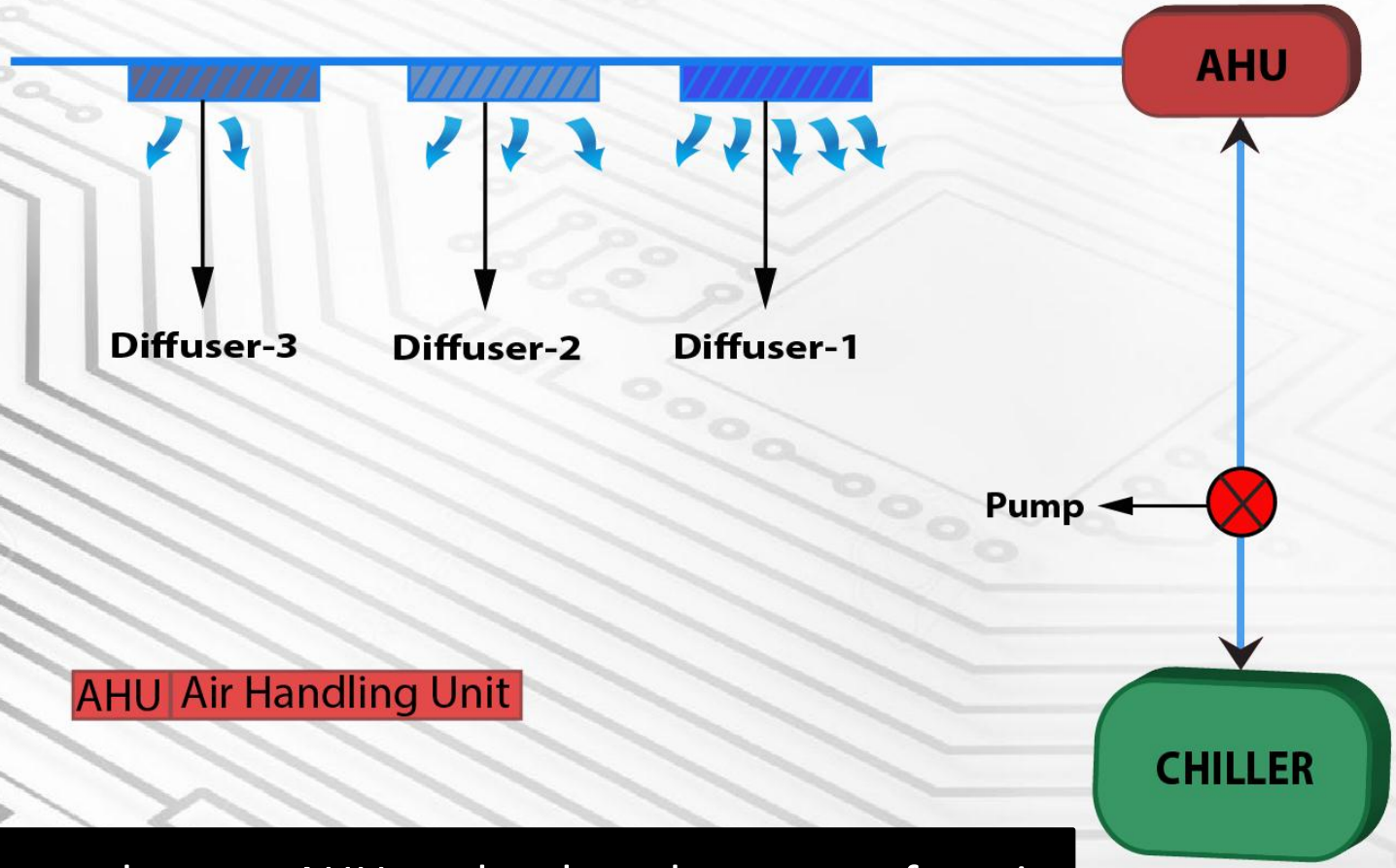


- DC Microgrid with DC appliances in each apartment (replaces 5A AC line)
  - 15A AC line remains at each home
- RBM (Remote Buzzer and Management) manages power to each apartment
  - Meters each apartment
  - Cuts out back-up power if exceeds pre-determined amount
- Can replace generator and provides huge energy conservation and savings

In Office Buildings

- Cooling may amount to 50% to 60% of total load
  - 50% in chillers and pumps
  - 50% in distribution: AHUs
- Office Building load mostly in day time
  - Coincides with solar hours
  - Cooling requirement proportional to solar-intensity
- Rooftop Solar PV can immensely help
  - Natural demand-supply match
  - Limited by available roof-top area
- Night time grid supply much cheaper than day-time

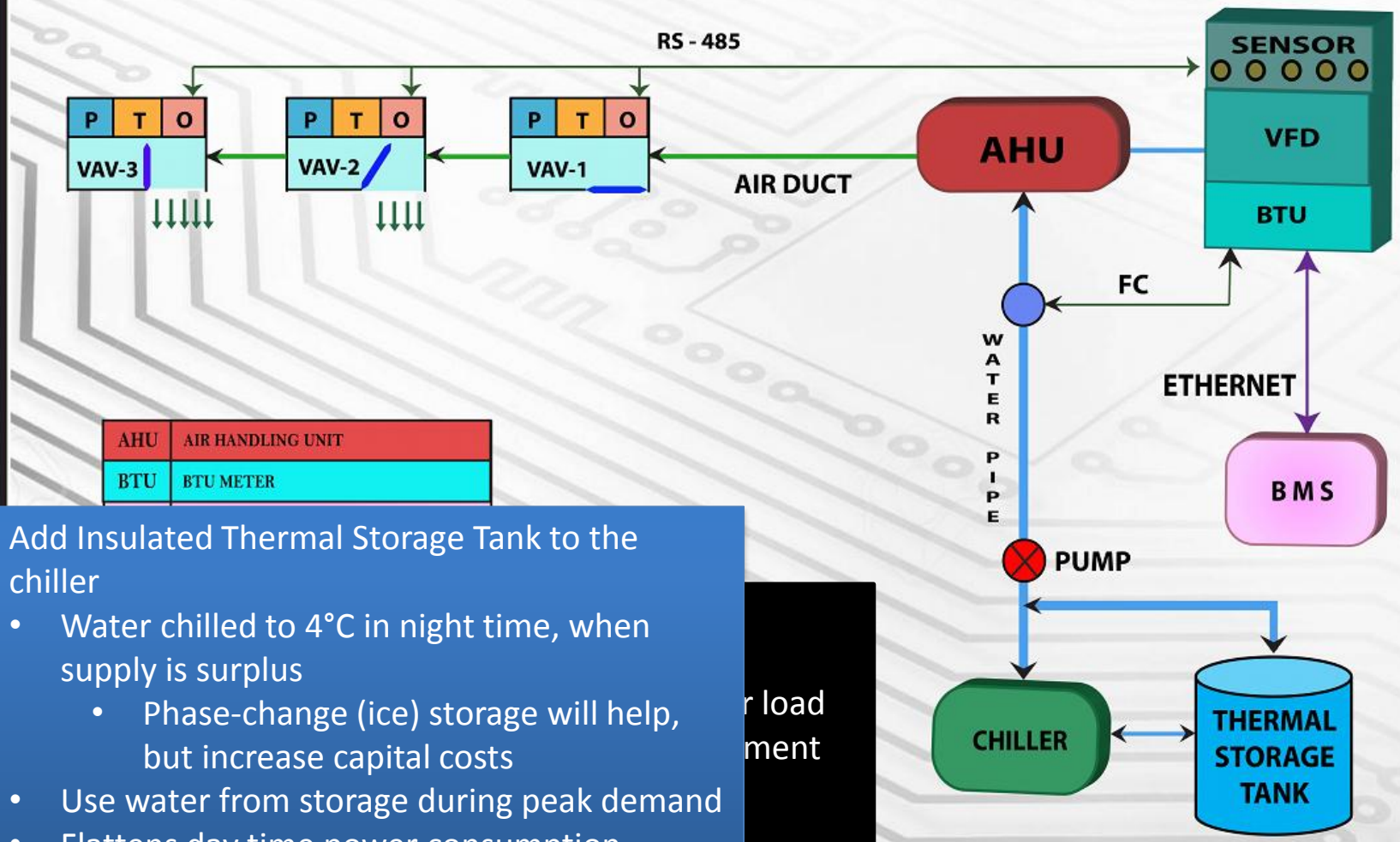
CONVENTIONAL COOLING SYSTEM



AHU Air Handling Unit

Spaces closer to AHU cooler than those away from it

GREEN BUILDING COOLING SYSTEM



Add Insulated Thermal Storage Tank to the chiller

- Water chilled to 4°C in night time, when supply is surplus
  - Phase-change (ice) storage will help, but increase capital costs
- Use water from storage during peak demand
- Flattens day time power consumption

Energy Efficient Buildings

- Should use LVDC Power line (48V DC) to power its lights, fans and electronic load (including all sensors)
- AHU should have Variable Airflow Volumes (VAVs) with sensors for air-distribution
  - Power VAVs and sensors using DC power
  - AHU should have integrated chilled-water BTU meters and flow-control
- Water pumps should have VFD or have BLDC / SRM motor and driven by solar directly
  - Should be able to pump most water when sun is there
- A higher Voltage (say 380V DC) power-line could feed DC power-lines in individual offices
  - Can be connected to solar
  - Could drive chiller, pumps, lifts (with VFDs) and AHUs

Electric Vehicles

GREEN TRANSPORT

Rational for going Electric

- India does not have much oil
  - Our oil imports are rising continuously and hurting Indian economy very badly
  - No solution in site in short, medium or long-term

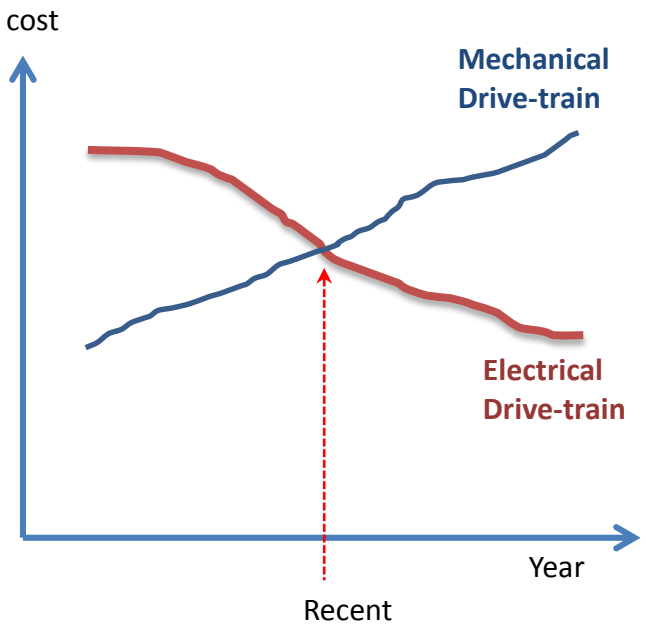
- Our cities and towns are highly congested
  - As middle class spreads, vehicle population continuously grow
  - Highly polluting urban India

The nay-sayers

- But do we not have shortage of electricity?
  - No significant off-peak hour shortage of electricity
    - Electricity generation continuously increasing
    - Need to discourage EV charging during peak hours
  - India has huge solar potential to charge EV in day time

- Do electric-generation plants not pollute?
  - Power generator pollutes much less than a vehicle for every Km even today
  - Much easier to manage reduced pollution in large electric plants as compared to in every vehicle
    - Technology can be further improved to reduce emissions
  - Power pollution is not in most congested areas
- Disposal of battery
  - Technologies fast evolving for battery-reuse and end of life safe disposal

Is Technology Ready?

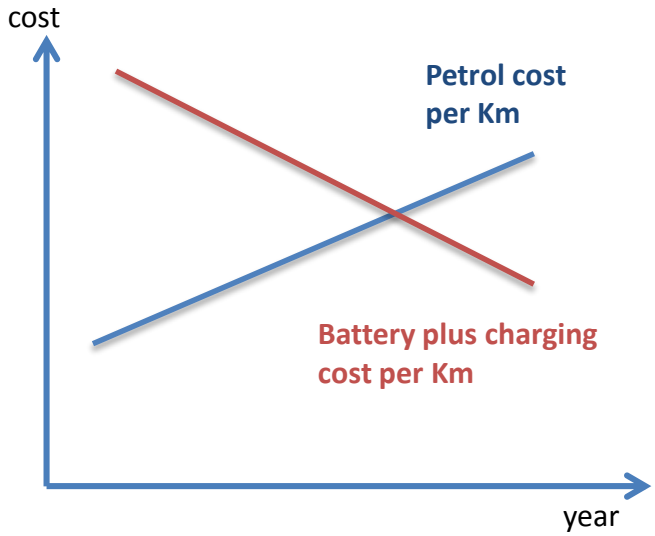


- For a vehicle **at volumes**, compare cost of mechanical (IC Engine) drive-train and electrical drive-train without batteries
- MDT cost goes up year after year (inflation)
- EDT cost goes down year after year (R&D, Moore's law and SW)
  - In recent times it crossed each other
  - Gap is to only increase year after year

Battery should be treated as fuel

Cost of Fuel

- Petrol cost per Km increases year after year
  - Though enhanced fuel-efficiency through R&D helps slow this
- Total cost of battery per Km (life-time depreciation, interest, maintenance and charging) keeps coming down
  - Battery R&D enhancing charge-discharge cycles and reducing costs continuously
  - Likely to only accelerate
- Crossover took place sometimes back



Li-Ion Battery costs are falling 8% per annum

Where Innovation and R&D is needed?

- Electric Drive-train
  - Motors (SRM) and Drive: will reduce kW/ km power usage
  - Battery Chemistry and
    - equally important Battery Engineering
  - Chargers: on-board and stand-alone
- Air-conditioners / heaters
  - Reducing heat load: glass / roof-tops
  - Penalty for air-con power-consumption higher in EVs vis-à-vis that in petrol vehicles
- System Controller and software

- Diesel / petrol Cars in India gradually replaced by EVs
  - By 2030 most vehicles in India could be electric
  - Help in India becoming pollution free
    - And most green nation Our dependence on imported oil considerably reduces
  - Our Power Industry gets load balancing and reduced **peaking**

To Sum Up

- Green DC-powered Homes driven by Solar-DC Inverterless
  - Power at affordable rates even during load-shedding
    - Lower / Middle Income homes can not afford power even at subsidised rates
  - will draw less from grid: reduces losses for DISCOM
- Green DC-powered Buildings with roof-top Solar
  - can reduce power-consumption by 30%
- Green Transport
  - Make us not depend on oil and make transport pollution-free
- 50% of Power produced using Solar by 2030
  - Decentralised solar and DC micro-grids to play important role