

# Growing Coal, Growing RE, DisCom Realities, and Carbon Implications

September 29, 2015

Rahul Tongia, Ph.D.

Fellow, Brookings

[rtongia@brookingsindia.org](mailto:rtongia@brookingsindia.org)

*also*

Adj. Professor, Carnegie Mellon  
Advisor, India Smart Grid Task Force  
Advisor, India Smart Grid Forum


# Disclaimer

- These slides are a slightly modified version of what was presented on 29<sup>th</sup> September at the Brookings Event – to enable readers to follow without having been present
- Brookings India holds no institutional view...

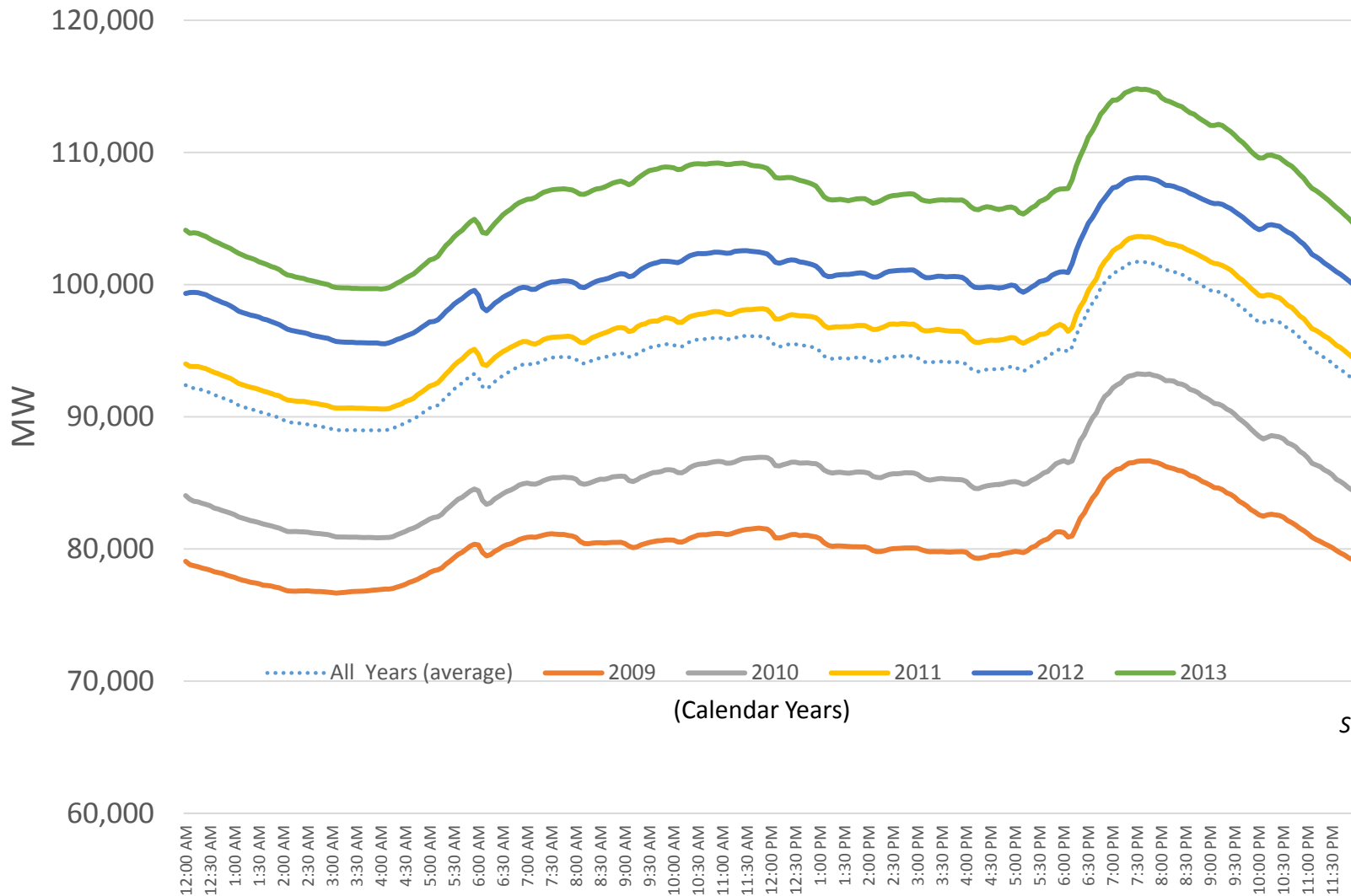
# Focus Areas for Discussion

- Want to consider the portfolio of energy (power) options...on the supply side mostly
- What is NOT the focus
  - Paris negotiations per se
  - Economics of DisComs per se
  - Any externalities beyond variable carbon (such as construction/other lifecycle), let alone fossil fuel externalities
- Focus includes
  - Grid integration
  - Utilities making a choice of what they want to run (load despatch)
  - Hidden and unknown issues (including costs)

# Looking out 5, 10, etc. up to, say, 35 Years

- 2050 is a VERY long ways
    - Compare India of 1980 and 2015!
  - Let's begin looking at the coming 5-10 years
    1. Extrapolate from today *identically* – A thought exercise only
    2. See what changes
      - Consumer mix
      - Tariffs
      - Time of Day Granular Demand
- 
- How do all these impact total system:
    - Efficiency
    - Cost
    - Carbon

# Avg. Daily Load Curve: All India Electricity Supply

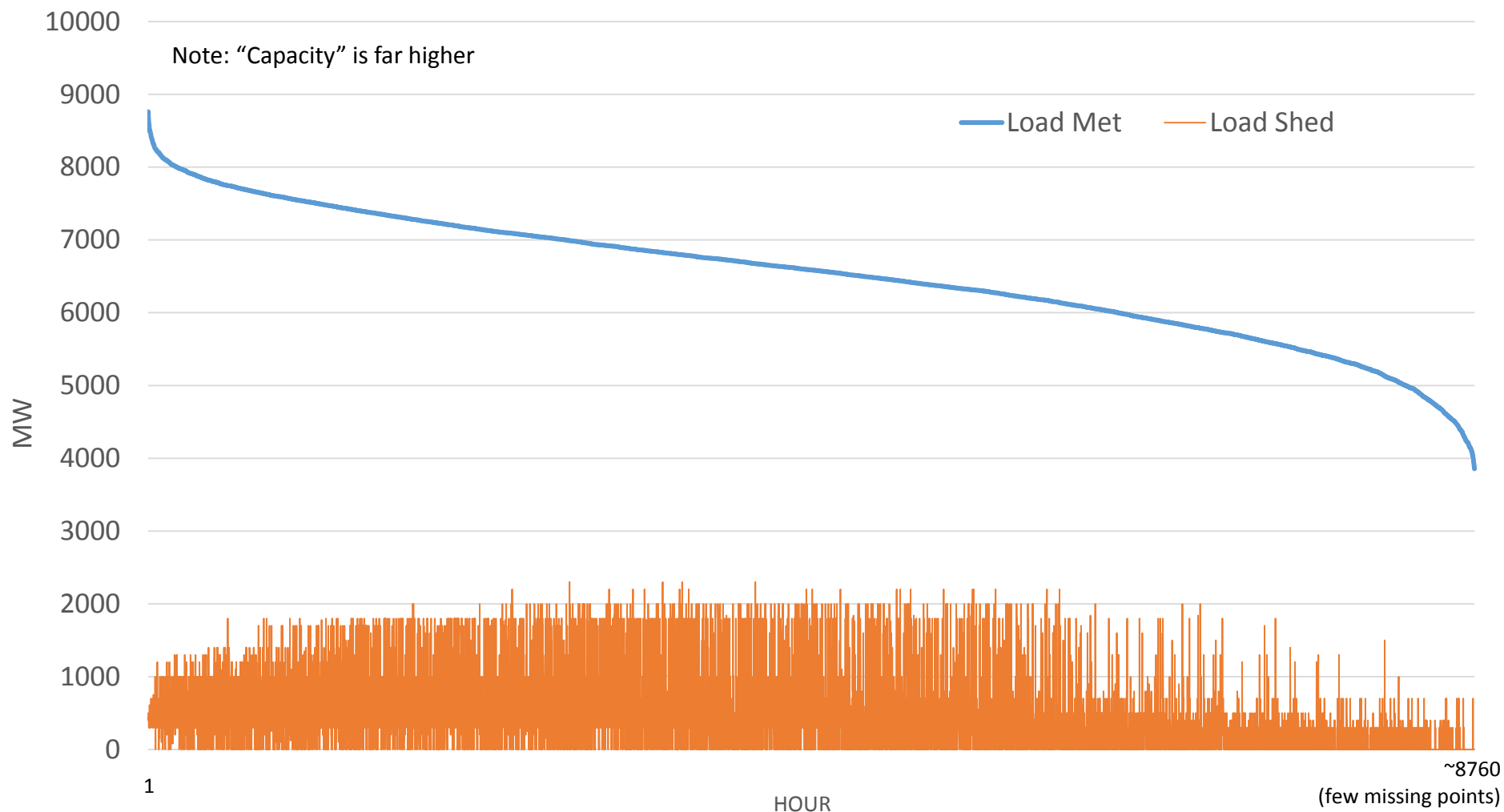


Source: NLDC data

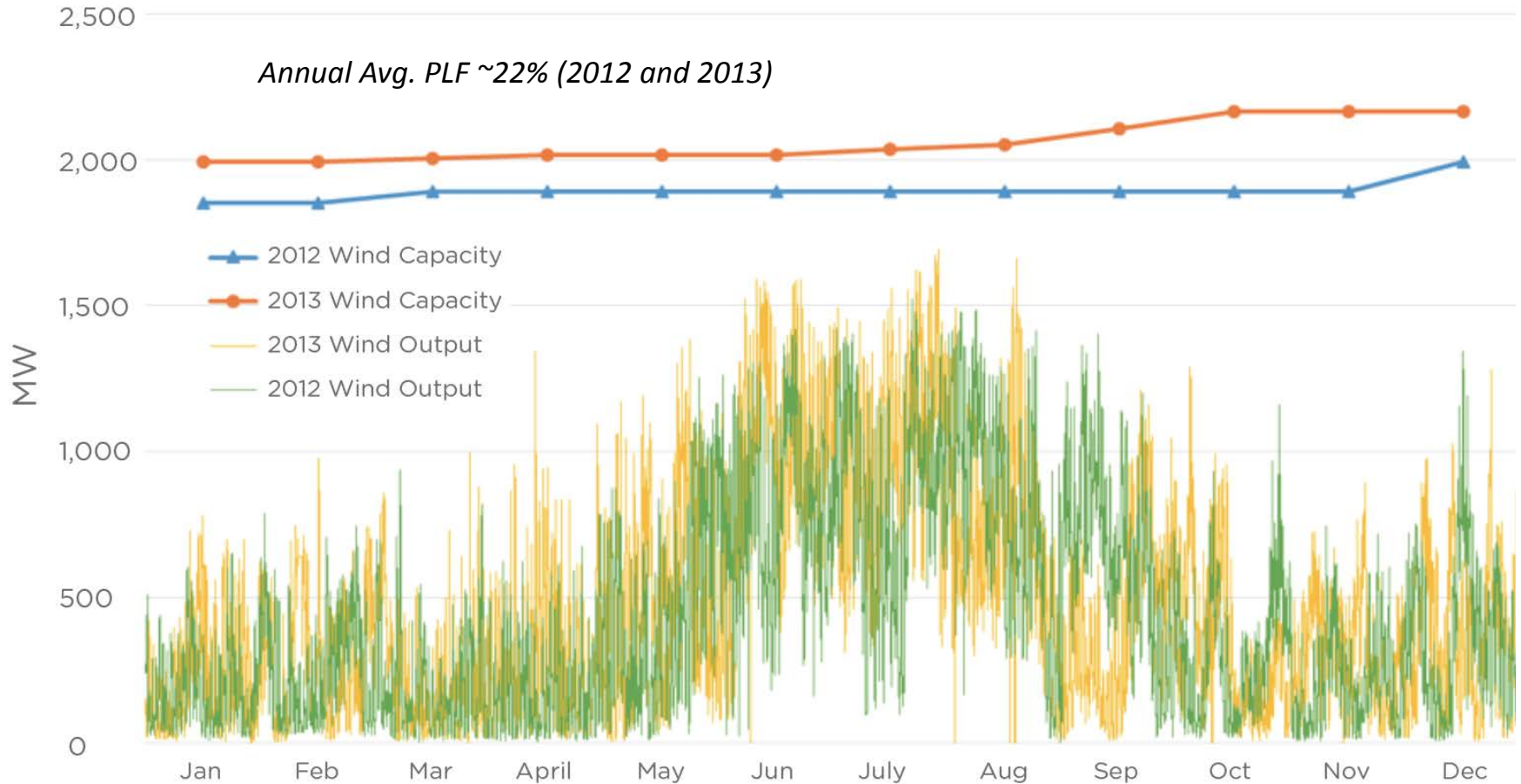
# Supply (last slide) vs. Demand: What is missing?

- See discontinuities (esp. morning and evening)
  - This is phase-rostering (and now feeder segregation)
- What about LOAD SHEDDING?
- Reality check: official shortfall methodology isn't instrumented, and is assumption driven
  - This impacts IPDS, 24x7 Power, Renewables Integration, etc.

# Karnataka 2013 Load Duration Curve



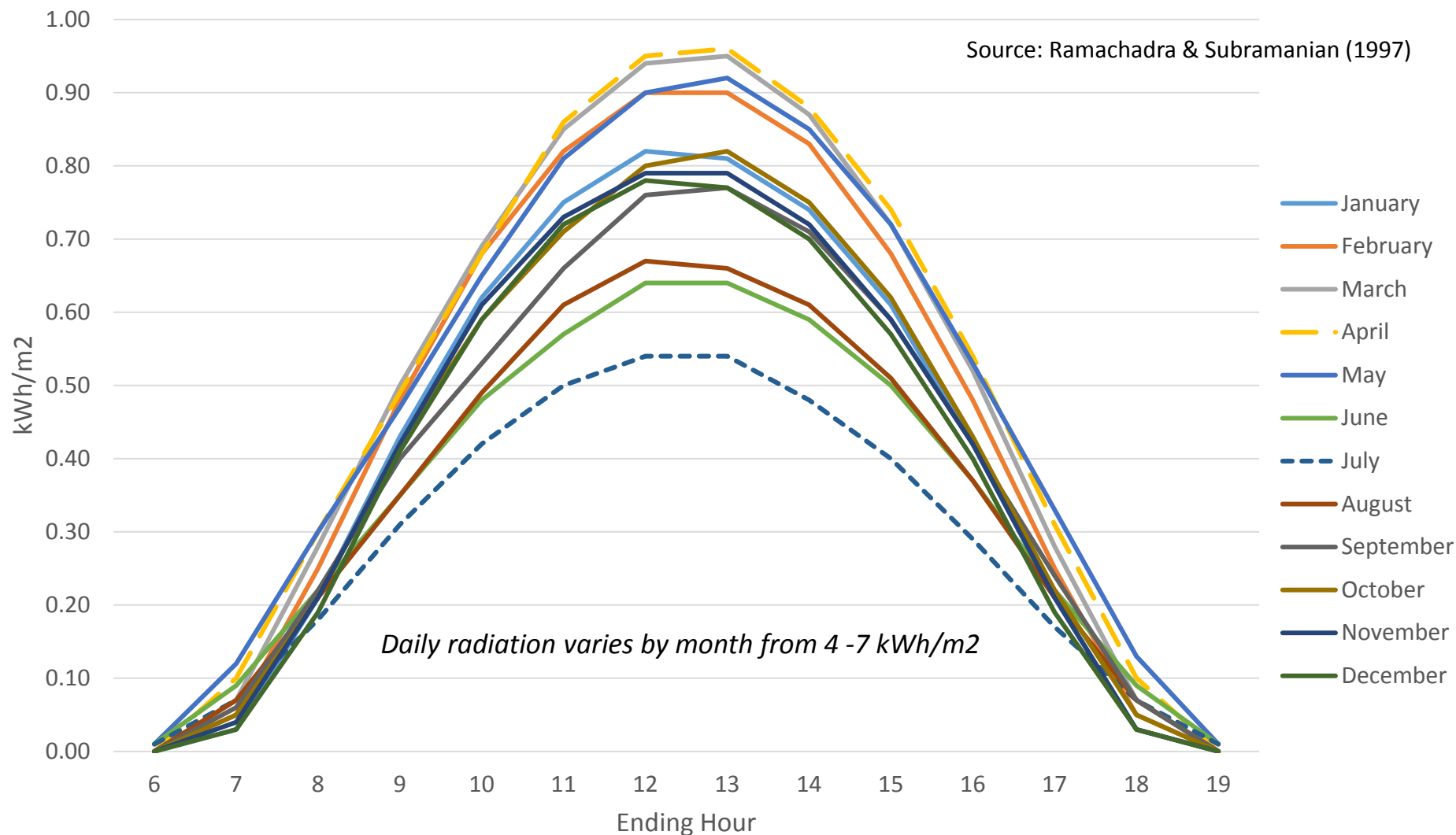
# Variability of Wind across Karnataka (1 minute resolution)



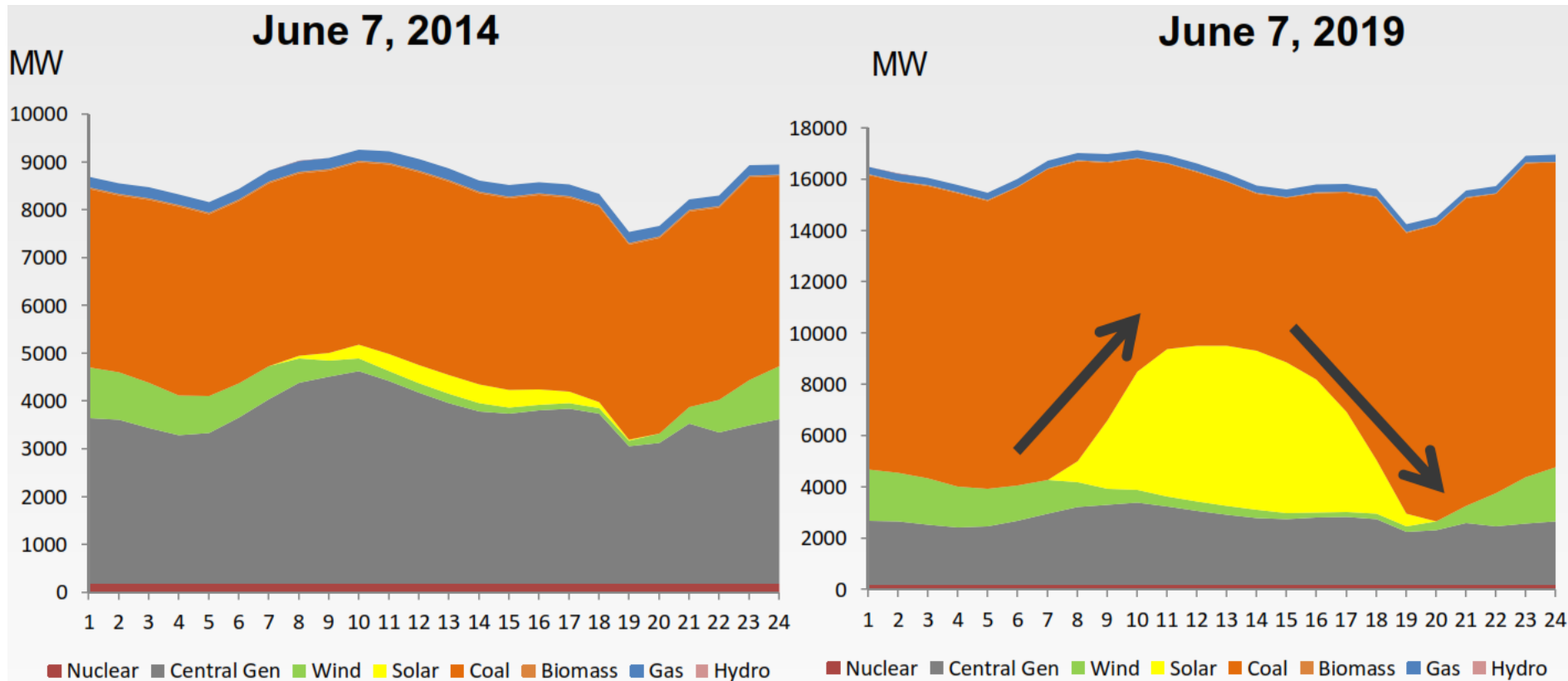
SOURCE: KPTCL Raw Data



# Hourly Solar Input in Goa



# Sample Rajasthan Load Curve Projection



Source: Wartsila

Need flexible generators suitable for ramping

Candidates: Open cycle gas turbine, hydro, and internal combustion engine – plus other storage, and demand response

# RE: Why India is “Different”

[Unlike Germany, USA, etc.]

- Our 6% RE (excl. hydro) is ~ to Germany’s 25%!
  - Germany has
    - Not just solar (fair amount of biomass/CHP)
    - A stronger grid
    - Interconnection to Europe (4+ times greater balancing)
  - *We have more trouble sharing RE across state boundaries than Europe has crossing national borders*
- We have a capacity problem, not an energy problem per se (have times of surplus)
  - Limited “peakers”
    - New Hydro is challenging for various reasons
    - Gas is limited (and few open cycle plants)

# “Dis-equilibrium”

- This isn't just “missing” equilibrium – this is when it isn't even attempted
- Wholesale prices  $< \text{Rs. } 3/\text{kWh}$  – yet DisComs not buying
  - Lack of (liquid) wholesale markets
    - Settlement terms
- States are not enamored of RE
  - Operational and financial concerns
  - “Grid Parity” is a misleading term

# PLFs and Backing Down is a Major Issue (not to mention ramping)

- In theory, techno-economics would chose which plant(s) to run – Load Despatch Center
- RE = Low marginal costs...BUT...
  - Hydro often is must run
  - LDC sees RE average costs
- What happens if we use one of two methodologies to value RE:
  - Negative Demand?
  - Additional load that can be served at the “same level of reliability”?

# US Electricity 2013

Power Source	Plants	Summer Capacity (GW)	% of total Capacity	Capacity Factor	Annual Energy (billion kWh)	% of Total US
Coal	518	303.3	28.61	0.595	1,581.12	38.44
Nat Gas	1,769	427.5	40.33	0.304	1137.69	27.66
Nuclear	63	99.2	9.36	0.908	789.02	19.18
Hydro	1,435	79.2	7.47	0.387	268.57	6.53
Other Renewables	2,299	82.6	7.79	0.35	253.5	6.16
Petroleum	1,101	43.5	4.1	0.071	27.16	0.66
Misc	78	2.3	0.22	0.675	13.59	0.33
Storage	41	22.4	2.11	-0.024	-4.68	-0.11
Import					46.73	1.14
Total	7,304	1060	100	0.443	4,112.70	100

# India Generation 2014-15

	Monitored Capacity (MW)*	PLF
NTPC	38,107.23	79.61%
Central (thermal)	55,649.73	73.96%
State (thermal)	65,473.49	59.83%
Private Util (thermal)	3,865.00	65.07%
Pvt. IPPs (thermal)	63,642.50	60.20%
Nuclear	5,780.00	80.74%
State (hydro)	24,581.70	31.40%
Central (hydro)	13,975.72	41.60%

\* As of March 2015

Source: CEA

State-Central plant dynamics will get further complicated by RE...

# Do we differentiate sub-optimally?

- State vs. Center
- Thermal vs. others
  - Draft policy: Thermal plants to cycle down to 55% output (esp. in response to grid conditions, e.g., RE)
    - This is akin to a marathon runner asked to run sprints!
      - Some compensation offered – not enough
    - Heat rate penalty – worse for cycling than steady state
    - Wear and tear
    - This can be amplified by the large size of many thermal plants



# How the Future will be different

- (Unrestricted) Demand will be less flat (=more peaking)
  - No load shedding
  - IP sets growth should plateau
  - Consumer demand growth
    - LEDs notwithstanding
- Other shifts
  - Electric Vehicles
  - Smart Grids

# Putting India's 175 GW RE by 2022 in C perspective

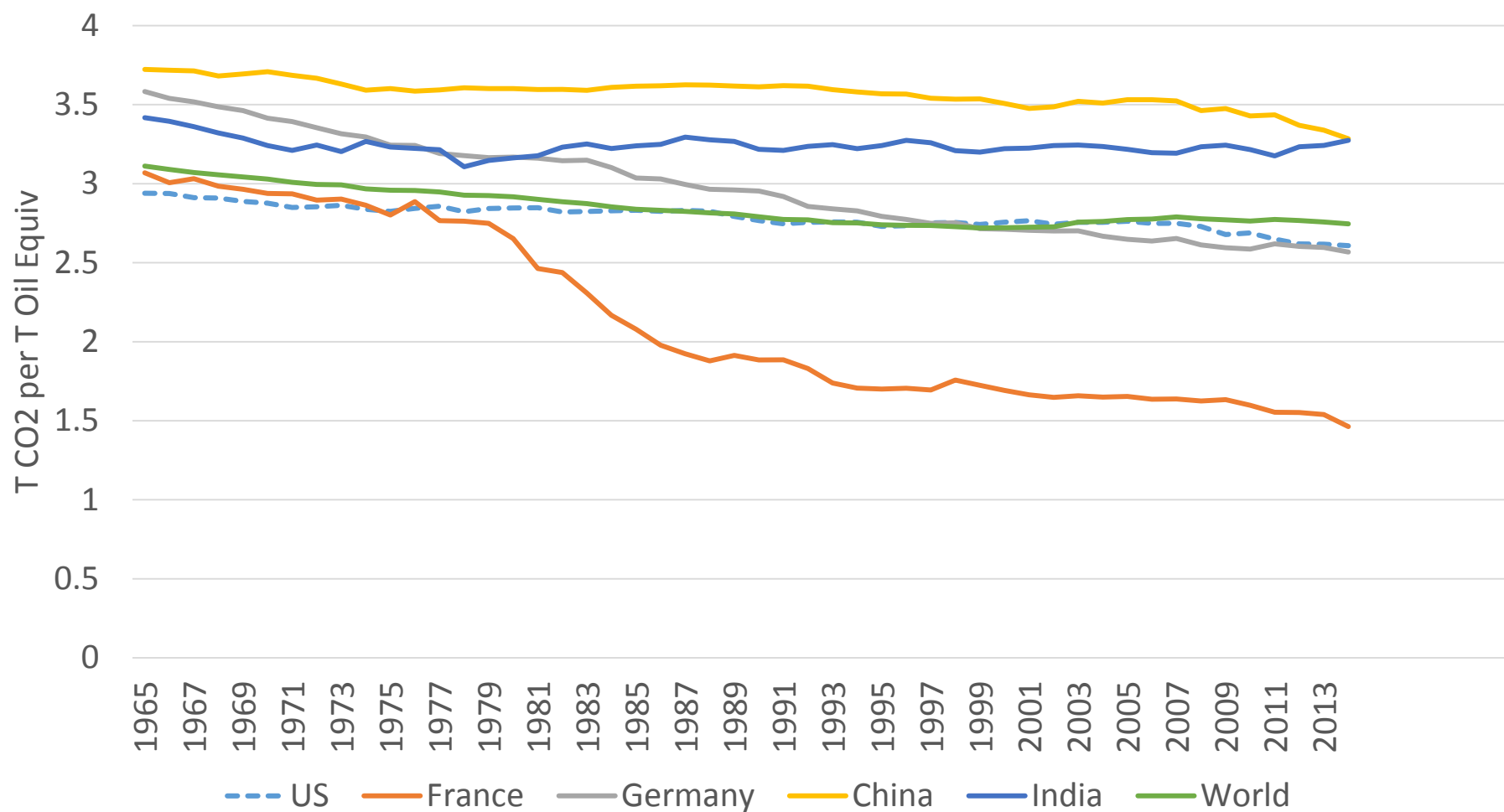
- 2015
  - 6% of power, on ~1000 BU total power base
- 2022
  - 4.375x RE power, but base also grows
    - Assume total grows 7% per annum total (disproportional RE)
      - While E intensity to GDP may be less than 1, there are mitigating factors
        - Past shortfall/electrification/etc. to manage
        - Future non RE growth may be more C than 2015 average (limited hydro growth)
        - Non-electricity energy use likely to grow faster (e.g., vehicles, industry, etc.)
        - Higher RE can impact thermal fuel efficiencies if ramping needs increase
- This means even this heroic effort is a power decarbonization of -1.1% only, maybe lower (due to mitigating factors)
  - This decarbonization is *electricity only, at best (limiting coal growth to keep total elec. growth 7% with high RE)*

# 7 Years Out - projections

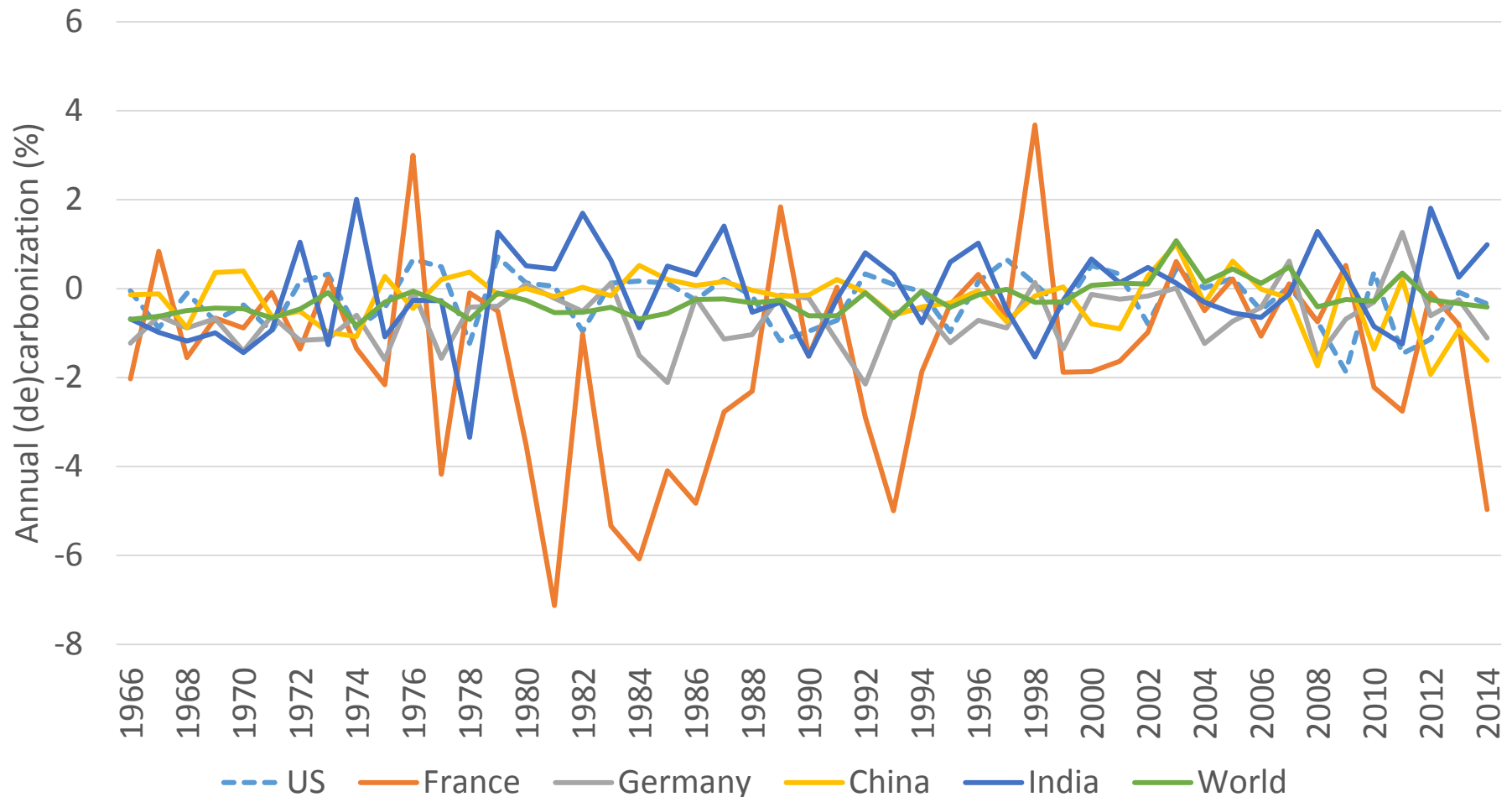
(Mid-year)	2015 Estimated	2022
Total Generation (BU) [gross]	1000	7% annual total growth → 1605.8
RE	60	175 GW RE → 262.5
Hydro	137	Limited new hydro; 12.5% growth → 154.125
Nuclear	36	40% growth → 50.4
Thermal	767	Balance is thermal → 1138.8

This implies a power decarbonization of power of -1.1% per annum over 7 years

# Carbon Intensity per Energy



# (de)Carbonization of Energy annual rates



# De(carbonization) observations

- Even France, which did very well in some years, wasn't consistent
  - Was building 30 large nuclear reactors simultaneously over 5 years
- For India to go down to 1.6 C intensity (T CO<sub>2</sub> per T Oil Equiv) by 2050 from 3.27 [2014] implies - 2.02% decarbonization of energy CAGR
  - Is it even possible (forget the cost)?
  - Ultimately, this must be coupled with similar heroic efforts on energy intensity

Average energy decarbonization CAGR (%) 1965-2014	
US	-0.16
France	-1.54
Germany	-0.73
China	-0.15
India	-0.14
World	-0.30

# Economics of RE: “It Depends”

- Multiple metrics of optimization
  - Carbon, cost, risk, etc.
- Multiple Stakeholders
  - Generator, State Load Despatch Center, POSOCO (aka ISO)
- One problem of RE and energy pricing – a single metric of “cost” = often the LCOE
  - Levelizing rates matter, and levelizing itself is fraught with assumptions
  - Variances and rates will vary, e.g., coal auctions might stabilize or even reduce coal prices

FIGURE 1: Solar Photovoltaics versus Coal Comparisons (4 Scenarios, 2014) — Coal — Solar

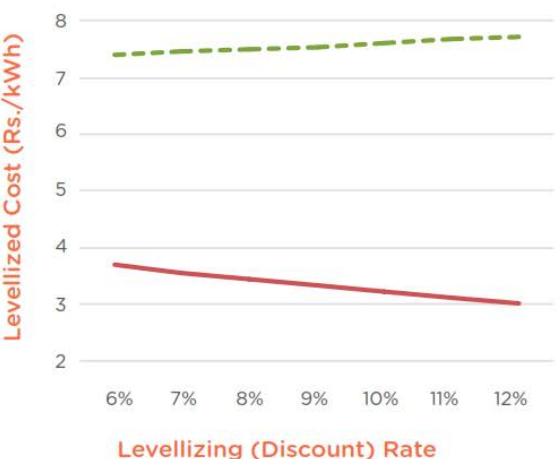
**Scenario 1:** • Expensive Imported Coal  
• Full coal costs (incl. Capex)  
• Single Best Open Solar



**Scenario 2:** • Imported Coal  
• Marginal Coal costs  
• Avg. Domestic Solar Category



**Scenario 3:** • Domestic Coal  
• Marginal Coal Costs  
• Avg. Domestic Solar Category



**Scenario 4:** • Domestic Coal  
• Full coal costs (incl. Capex)  
• Avg. Open Solar Category



# Comparing Coal and Solar

- Key issues
  - Domestic vs. Imported coal
  - Solar type
    - Domestic vs. Open
    - Best or average (bids)
- Marginal or avg. coal costs
- Trends of escalating inputs
  - Fuel
  - Inflation
  - Forex

Source: *Blowing Hard or Shining Bright? Making Renewable Power Sustainable in India* (2015) [Brookings India]



# Challenges and Options

1. Grid Integration
  - Variability and Stochasticity are BOTH issues
  - Evacuation is a subset of the problems
2. Pricing power better (procurement, before worrying about retail)
3. Measuring variable emissions
  - Carbon and more
    - Ramping causes efficiency penalties on thermal plants

# Options for the Future

## 1. Signaling for Grid Optimality

- Larger Balancing Areas or at least better flows between areas
- Proper ancillary services (more than just primary frequency control)

## 2. New markets and systems to capture marginal costs

- ToD pricing
  - Peaking supply
    - Neither Coal nor RE may work for this
  - Locational Marginal Pricing for transmission
- *Valuing load-shedding as having a cost!*
- Wholesale markets
  - NOTE: India lacks Mark-to-market pricing for most kWh
    - RE can make wholesale prices negative!

## 3. Need to capture instantaneous outputs (not just averages)

- New Reporting schemes
- New Rating Schemes (e.g., Green Ratings)

# New Reporting Mechanisms

- REMCs are just a start (focus: predictions and monitoring)
- Need standardized, online, granular reporting
  - *First step is instrumentation*
    - This also ends mistrust
  - Power Plants
    - Output
    - Input (fuel)
      - Effective heat rate
    - Marginal costs
    - Technical back-down
    - Economic back-down
    - Emissions monitoring in real time (local emissions are a major issue)
  - DisComs (ideally feeder level)
    - Demand
    - Rostering and Load shed

# Policy Suggestions (cont.)

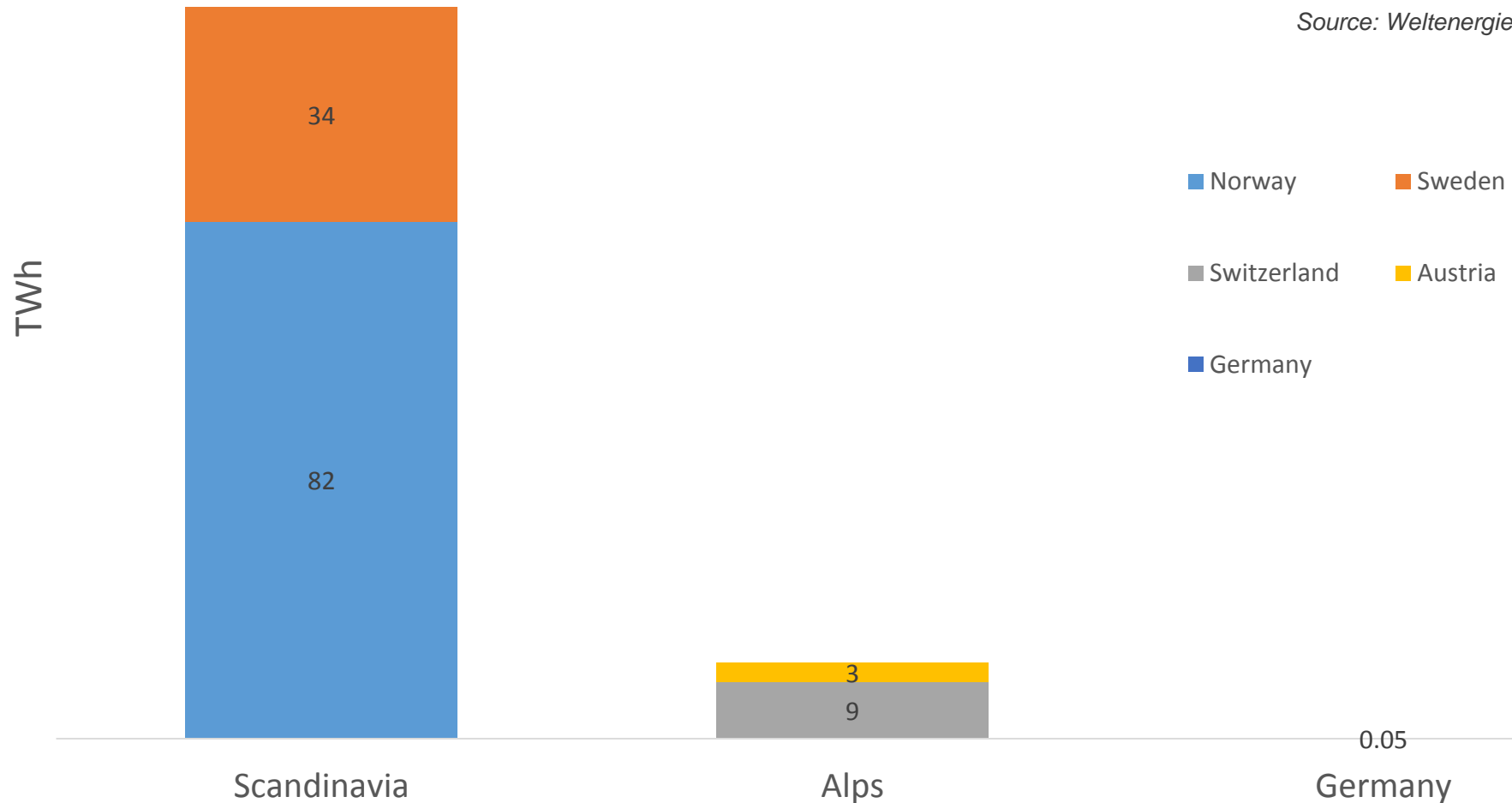
- Green (and other Ratings)
  - Today's Utility Ratings (e.g., ICRA) do not sufficiently link finances with operations
    - Quantum of load shedding
    - RPO compliance and share of RE
- Implicit cost of load shedding
  - Is already a cost – passed on to consumers
    - Paying for removing load-shedding may need inter-ministerial transfers (e.g., kerosene reduction)
  - Same tools to manage load-shedding can help with variability of RE (e.g., visibility, peakers, balancing, Smart Grids)
  - Ending load-shedding may take time
    - Can we start with penalizing *unscheduled* load-shedding?

# Rethinking RPOs

- Hydro (and storage) may be key enablers
- If a neighboring state has hydro (or, better, pumped hydro), can they be credited for sharing that?
  - Same could apply to Demand Response (Smart Grids)
- Suggestion: re-think an RPO to include enabling support (hydro, pumped hydro, demand response, etc.) *as specifically linked to greater RE*
- IF one had the markets, one could do it via economic signaling
  - Europe already shares hydro storage and pumped hydro across national borders (esp. for RE)

# Pumped/Storage Hydro in Europe – Aimed to enable more RE

Source: Weltenergierat



# Fundamental Qs

- How do we better optimize the portfolio of supply?
- If RE is negative demand, and “must run”, does this impact the PLFs of new coal?
- Is there a point when RE isn’t a new kid on the block (worthy of support) but more the core?
  - What does that do to the grid?
- How do we avoid the Utility Death Spiral?
  - Worsened in India due to tariff distortions ala subsidies
  - Need to figure out the role of the grid (utility), and the costs
- At what point would a developer say, “coal plants aren’t worth it”?
- Can we get granular carbon monitoring and green ratings for power plants?

Armies cannot stop an idea whose time has come

– Victor Hugo