Do rural residential consumers cross-subsidize their urban counterparts?

Exploring the inequity in load shedding among metros, towns and villages

Santosh M. Harish and Rahul Tongia
santosh.harish@povertyactionlab.org / rtongia@brookingsindia.org

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Department of Engineering and Public Policy,
Carnegie Mellon University

Research Questions

1. How do load shedding schedules in metro, small town and rural feeders compare?
2. Are tariff differences an adequate explanation for the load shedding disparity?
3. Is uninterrupted, but current limited, supply viable?

Why should we frame this in terms of cross-subsidies?

- Claim: Favorable treatment for the metros is necessary
  - Supply deficits exist
  - Costs of supply: higher in rural areas, than in urban
  - Revenues: lower in rural than in urban, because tariffs and consumption levels are lower
  - Distribution utility needs to be financially viable

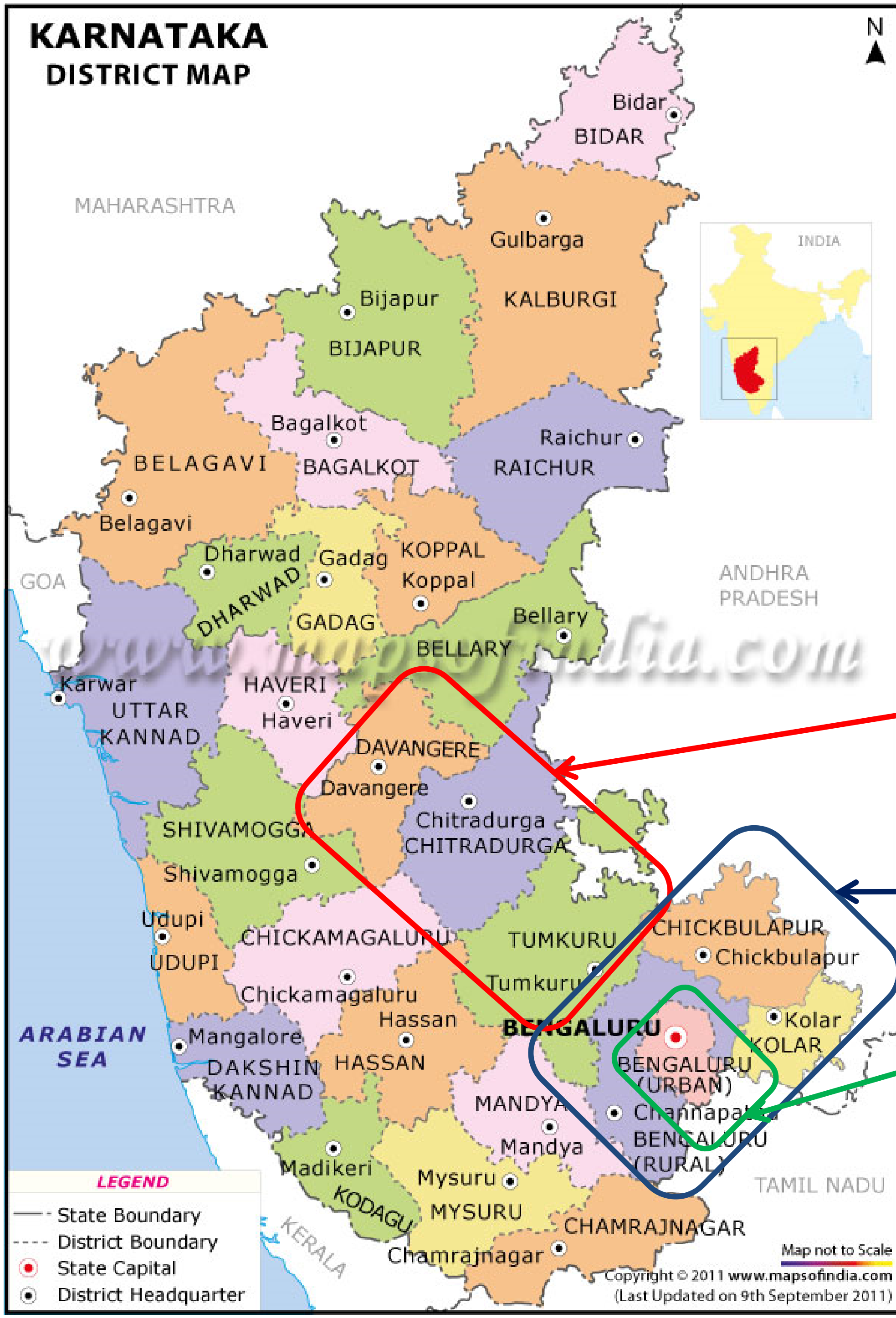
  Q: Does the relief provided by load shedding rural consumers more than compensate for tariff subsidies they receive?

- Claim: Tariff differences between rural and urban residential consumers introduced to reflect poorer supply
  - Tariffs are lower because the supply is poorer, not the other way round

  Q: Do the tariff differences sufficiently account for the differences in supply?

Data source

- Karnataka Supervisory Control and Data Acquisition (SCADA) systems, courtesy KPTCL
- Nature of data
  - Minute-wise details on consumption and supply for every 11kV feeder
- Geographical region and dates
  - 9 days (3 each from Sep '12, Dec '12 and April '13) of data from Chitradurga- Tumkur zone, and NRS substation 'representative' from Bangalore Metropolitan zone
  - Entire BESCOM area for 3 days (1 each from Sep '12, Dec '12 and April '13)
  - Additional validation using HESCOM data from Sep '12 and Dec '12



BESCOM zones and districts covered

Chitradurga-Tumkur zone: Davanagere, Chitradurga, Tumkur

Bangalore rural zone: Bangalore rural, Kolar, Chickballapura

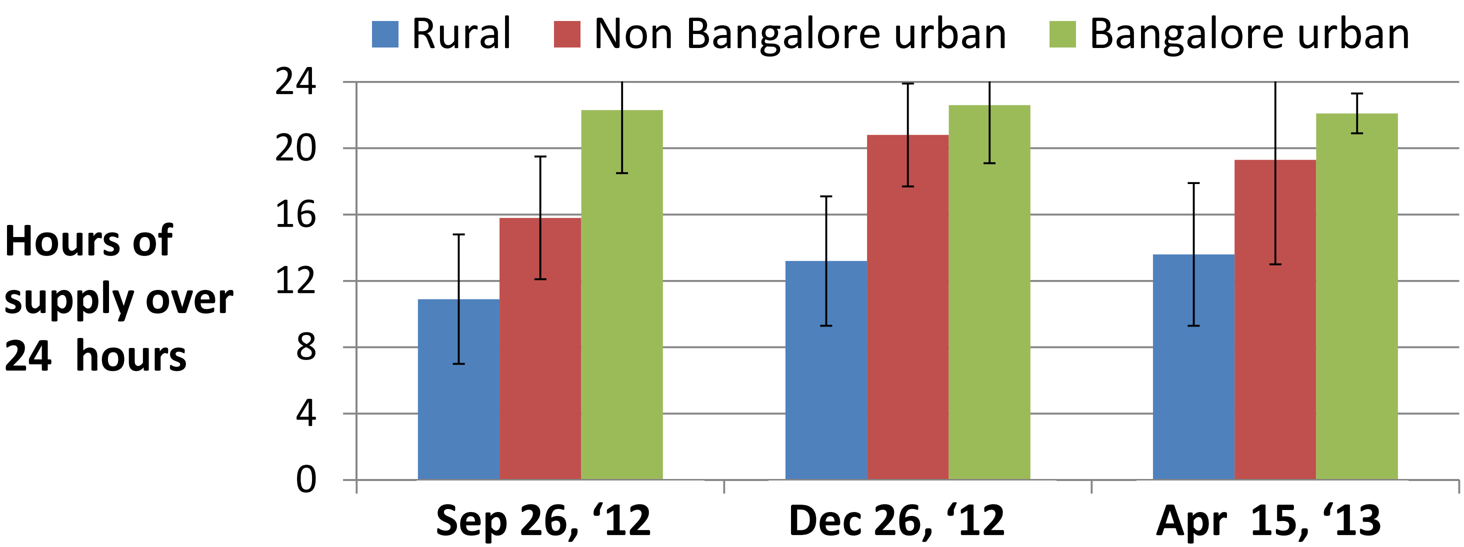
Bangalore metropolitan zone: Bangalore urban

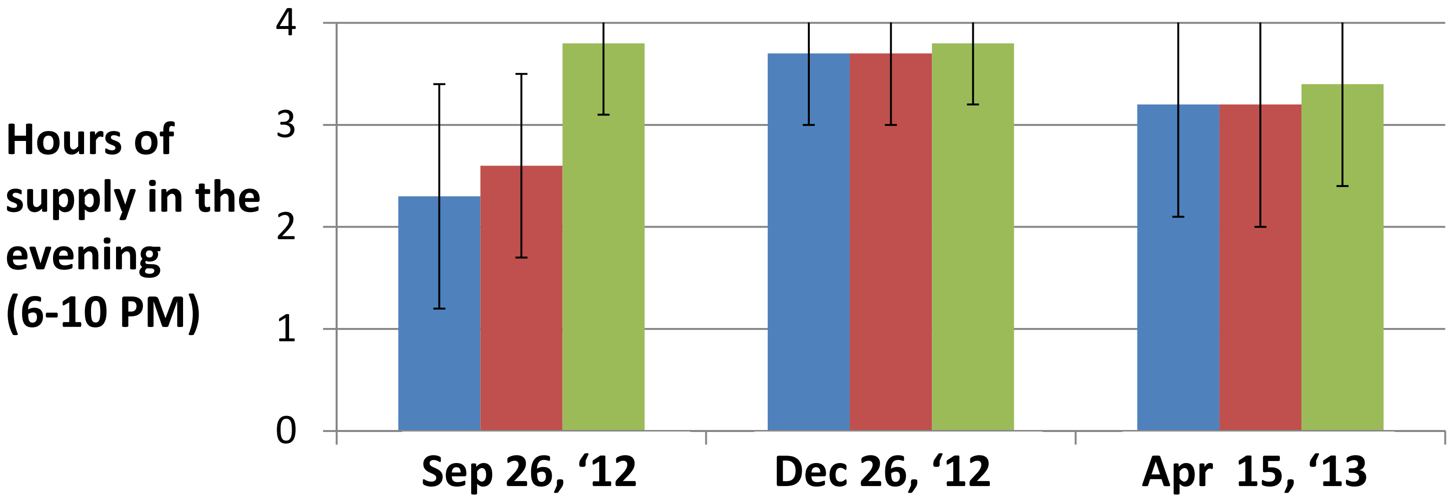
The many kinds of subsidies

Consumer category	Number of consumers	Total cons. (MU)	Average monthly cons. (kWh)	Revenue/ month/ consumer (Rs.)	Revenue per unit (Rs./kWh)
Rural- poorest *Bhagyajyothi*	0.7 million	110	13#	65*	**5***
Irrigation pump-sets (<10HP)	0.7 million	4,300	530#	700*	1.3 *
Rural residential	1.6 million	550	28	92	3.4
Urban residential	4.2 million	5,600	110	470	4.3
LT Commercial	0.8 million	1,800 (U) 100 (R)	210 (U) 90 (R)	1,600 (U) 660 (R)	7.6 (U) 7.3 (R)
HT Industrial	4,900	5,800	100 ,000	600 ,000	6
HT Commercial	4,800	3,900	68 ,000	540 ,000	8

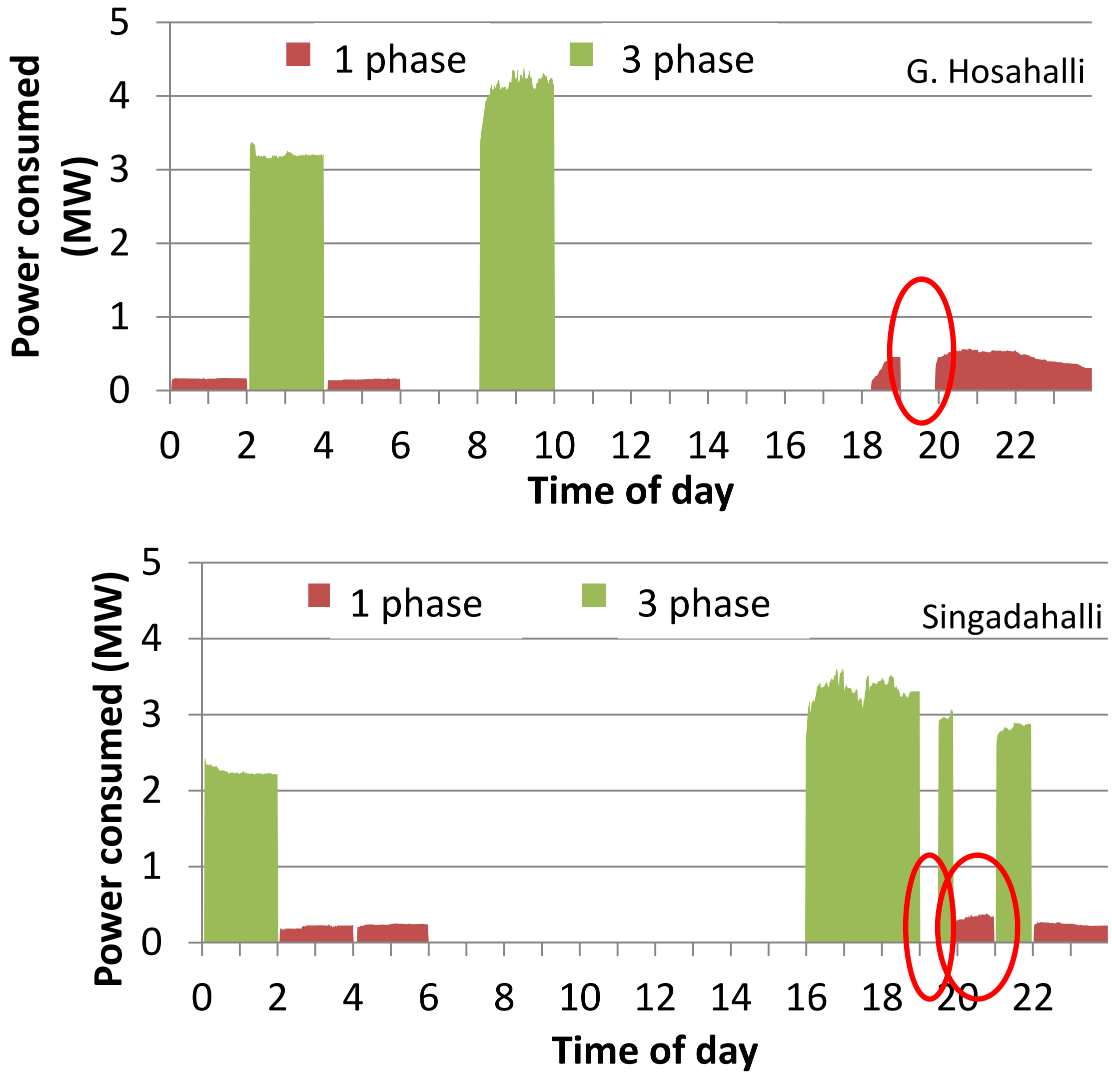
#- Not always metered, and hence presumptive
*- Subsidized by Government of Karnataka

Supply availability in BESCOM feeders





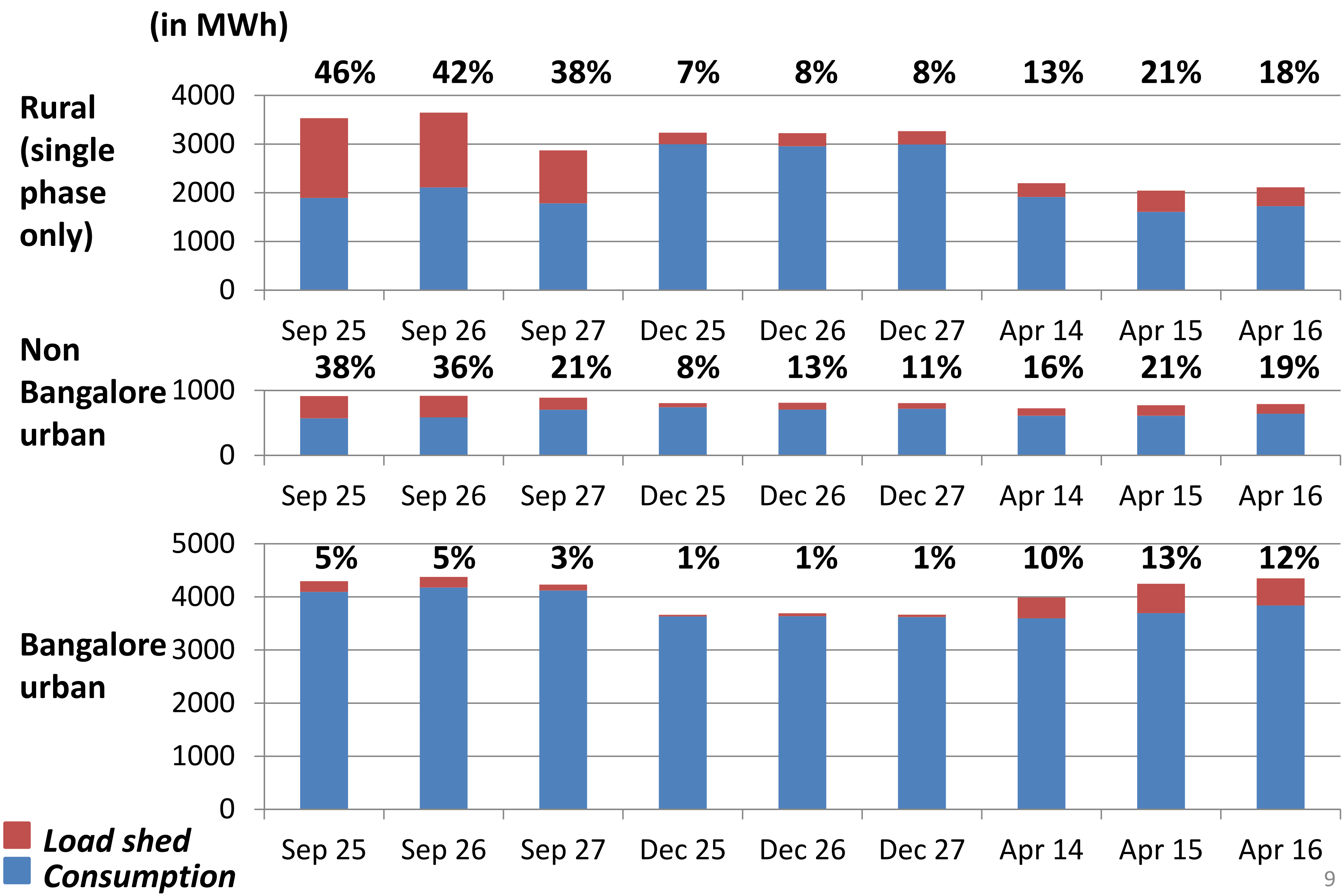
Estimating the shed load



- Evenings only
  - Peak for both rural and urban domestic
- Interpolation to estimate load shed
- Only single phase consumption
  - No pump-sets

These are rural feeders in Gubbi Substation, Sep 26 2012

Estimated evening demands and load shed



Framing the "cross-subsidy"

Tariff based transfers

- Consumptions are known
- Estimate common tariff structures which are revenue neutral, and account for the higher costs of supply in rural areas

- Function of consumption and difference between regular and common *average* tariffs

Load shedding based transfers

- Load shedding levels known
- Estimate unrecovered costs if rural and non Bangalore urban consumers are load shed at the Bangalore urban level

- Function of loads shed, procurement costs at peak and *marginal* tariffs

Calculating tariff subsidies

		Rural	Urban
Number of consumers (million)		1.6	4.2
Average monthly consumption (kWh)		28	97
Monthly fixed charges (Rs.)	For the first kW	15	25
	Every additional kW	25	35
Variable charges (Rs./kWh)	0- 30 kWh	2.4	2.5
	31-100 kWh	3.4	3.7
	101-200 kWh	4.55	4.85
	>200 kWh	5.35	5.85
Average revenue per unit Rs./kWh#	At approved tariffs for 2012-13	3.5 (R)	4.2 (U)
	Step 1: If rural households paid urban tariffs	4.1	"
	Step 2: Adjusting the common tariffs so that total revenue is unchanged*	4.0 (R')	4.1 (U')
	Step 3: Accounting for higher distribution losses in rural feeders	4.2 (R'')	4.1 (U'')

Approved tariffs for 2012-13

Tariff subsidies to rural consumers = R'' – R = Rs. 0.7/ kWh

Tariff subsidies from urban consumer = U – U''= Rs. 0.1/ kWh

- All calculations based on D21 sheet of BESCOM's filings to KERC and inputs therein

*- Both revenues from fixed and variable charges are kept unchanged

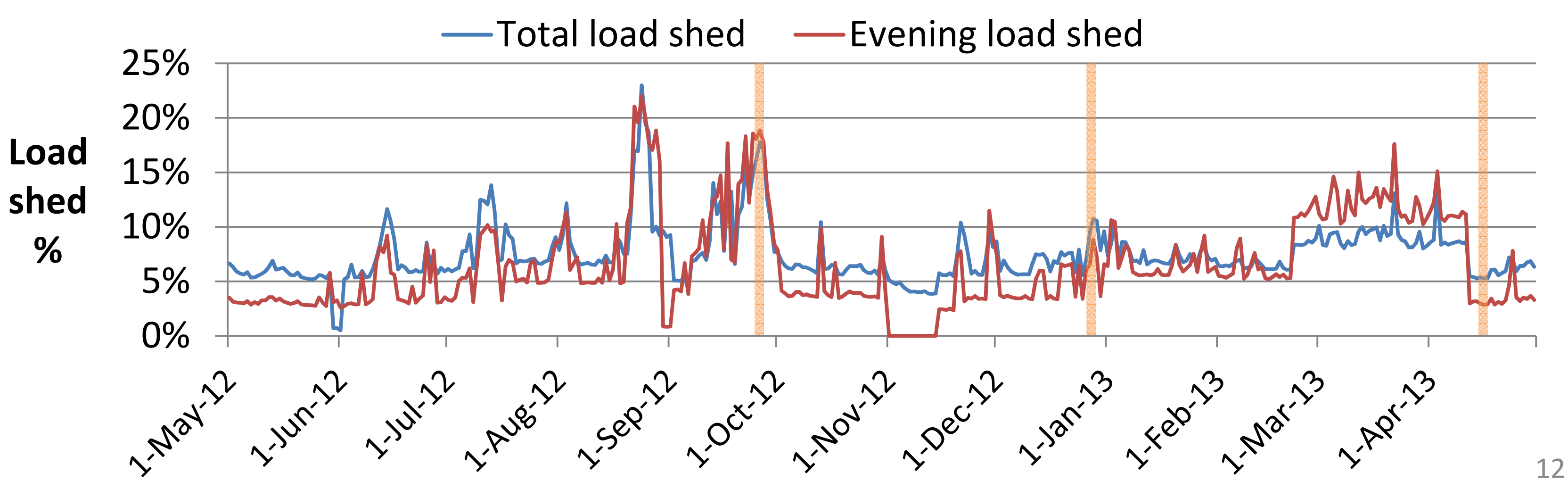
Calculating load shedding transfers

$$\text{Load shed relief from a given feeder category} = \frac{\underset{MWh}{(\text{Actual load shed} - \text{BU load shedding level})} \times \underset{\%}{(1 - \text{frac}_{\text{non-domestic*}})} \times \underset{Rs./MWh}{\left[\text{Cost of procuring and supplying peak power} - \text{“Unsubsidized” Marginal tariff}\right]}}{\text{Total number of domestic consumers in the feeder category (i.e. R/BU/NBU)}}$$

(Rs./ consumer-day)

*Non-domestic consumers here include Bhagyajyothi households and commercial consumers

- This is calculated for the 9 days for which we have data
- Annual estimates are then made by mapping all the days in the year into one of these 9-day types based on state level demand and load shedding as per KPTCL



Rural-urban transfers for the 9 days

		Sep '12	Dec '12	April '13
Rural	Load shed (%)	37-45	8-9	13-21
	Tariff transfer (Rs./consumer-day)	-0.2 to -0.3	-0.4	-0.2 to -0.3
	Load shed transfer (Rs./consumer-day)	+2.6 to +3.8	+0.5 to +0.6	+0.2 to +0.4
Non-Bangalore urban	Load shed (%)	26-36	7-11	16-21
	Tariff transfer (Rs./consumer-day)	+0.05 to +0.06	+0.06	+0.05
	Load shed transfer (Rs./consumer-day)	+1.2 to +2.3	+0.4 to +0.6	+0.3 to +0.5
Bangalore urban	Load shed (%)	16-22	4-7	10-13
	Tariff transfer (Rs./consumer-day)	+0.05	+0.04	+0.04
	Load shed transfer (Rs./consumer-day)	-1.4 to -2.1	-0.3 to -0.4	-0.1 to -0.3

'+' transfer **from** category **'-'** transfer **to** category

Net transfer **from** category (green) Net transfer **to** category (red)

Ranges in values are due to the three days for which the calculations are made

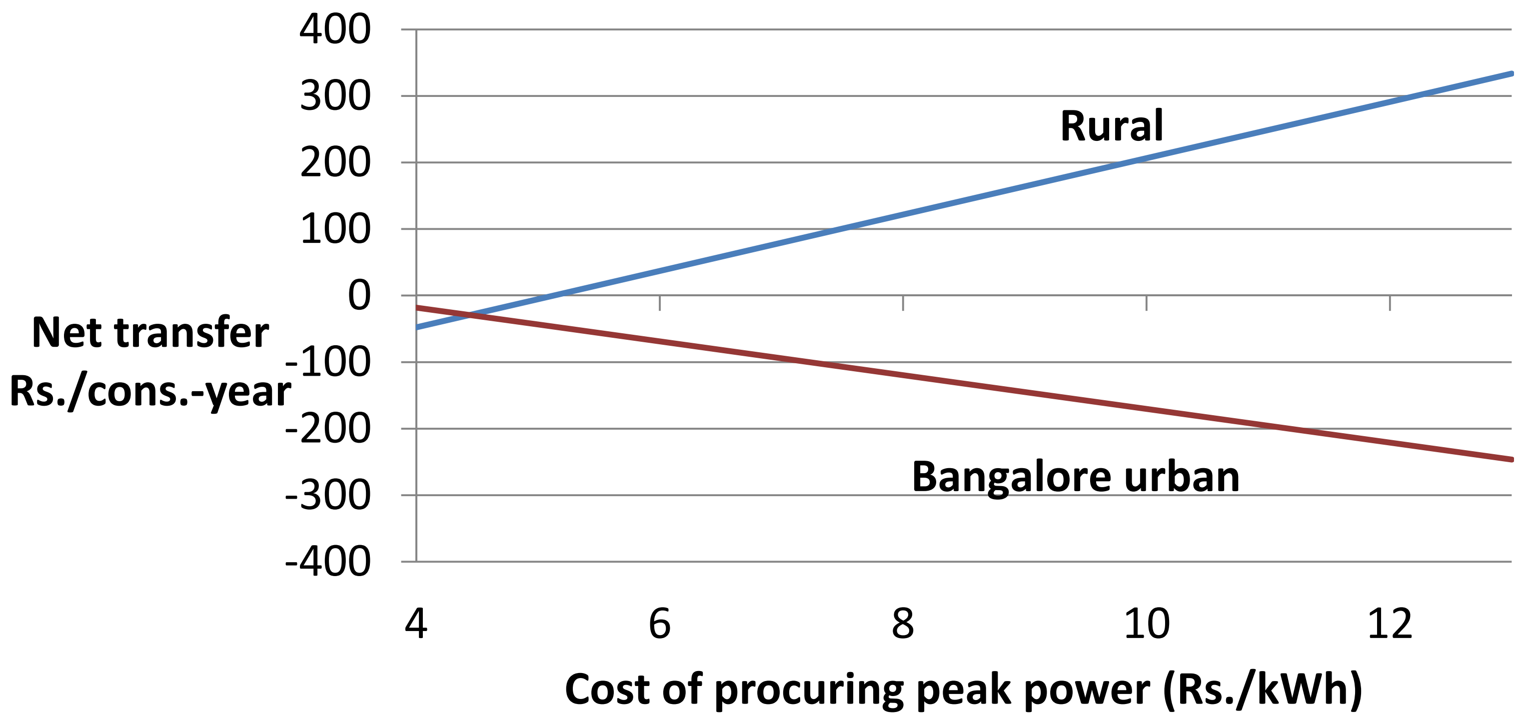
Annually, who subsidizes whom?

Classification criteria for weighting	Annual load shed transfer (Rs./residential consumer-year)			Annual net transfer (Rs./residential consumer-year)		
	Rural	Non Bang Urban	Bangalore urban	Rural	Non Bang Urban	Bangalore urban
Unscheduled and scheduled evening load shed	+240	+200	-140	+120	+220	-120
Total unscheduled and scheduled load shed in 24h	+230	+200	-140	+120	+220	-120
Unscheduled and scheduled load shed and demand- evening	+320	+260	-190	+190	+280	-170
Total load shed and demand in the evening	+510	+350	-290	+380	+370	-270

+ transfer **from** category
- transfer **to** category

The results vary depending on the criteria used to categorize the days of the year, but the conclusion remains the same :
Net positive transfer from rural and non Bangalore urban, net negative from Bangalore urban

Results are sensitive to procurement costs - but the direction of net transfers is robust



+ transfer **from** category

- transfer **to** category

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Putting the transfers in perspective

- Annual load shedding transfers of Rs. 240-510/ rural consumer
  - On average, 20-44% of annual electricity expenditure
- Net transfers in terms of annual electricity expenditure
  - 20-60% for the poorest three rural deciles
  - 10-36% for the richest three rural deciles
- Not just rural-urban disparity, but the load shedding is regressive and impacts rural poor disproportionately
- Kerosene expenditure for the poorest 30% of the population is on average equal to 85% of their electricity expenditure

And in aggregate…

Classification criteria for "similarity"	Annual load shed relief (Rs. in crores)			Annual net "subsidy" transfer (Rs. in crores)		
	Rural	Non Bang Urban	Bangalore urban	Rural	Non Bang Urban	Bangalore urban
Unscheduled and scheduled evening load shed	+40	+11	-51	+20	+12	-45
Total unscheduled and scheduled load shed in 24h	+38	+11	-49	+20	+12	-44
Unscheduled and scheduled load shed <u>and</u> demand- evening	+54	+14	-68	+32	+15	-62
Total load shed and demand in the evening	+85	+19	-104	+64	+21	-98

+ transfer **from** category

- transfer **to** category

Aggregate net transfers do not sum to zero, as the tariff subsidies considered here are restricted to consumption in the evenings

Rural-urban welfare transfers nationally

The load shedding difference between rural and urban feeders is likely to be a function of peak load shedding in each state, and the fraction of state peak demand from rural domestic consumers. Based on this, we can get national estimates

	Load shed relief Rs. Crores/ year	**Net transfer (Rs. Crores/ year)**
BESCOM	40-80	20-60
Nationally- 30x	1200-2400	600-1800
Nationally- 50x	2000-4000	1000-3000

- This is assuming that the tariff subsidies (urban-rural) are similar across the country
- In terms of welfare transfers, this is in addition to large fractions of rural households not being electrified in many states
  - -Unelectrified: Bihar- 90%, Uttar Pradesh- 76%, Assam- 72%, West Bengal- 60% (Census 2011)

Reducing the inequity in load shedding

Load shed all consumers "uniformly" ←→ Meet demand by procuring additional power (i.e. no load shedding)

Explore the continuum between these extremes

- Procure some additional power and limit outages to an intermediate "optimal" level

- Procure some additional power and provide uninterrupted, but current limited, supply (using e.g. smart meters)

When are installing current limiters viable?

Rural consumer	Central Government	Utility		
Savings in expenditure on kerosene	Savings in subsidy for kerosene	Load shed relief *Less* (Tariff subsidy + Unrecovered cost of peak power)	>	Cost of installation of smart meter (amortized)
Avoided interruption costs even if load shed ‘equitably’				

- Backup is primarily kerosene for lighting in rural consumers
- Willingness to pay from rural consumers will likely be higher
- This is being calculated for the “average rural household” in the “average village (rural feeder)”
  - In principle, the analysis could be more granular

Economics of installing current limiters

Load-shedding is replaced by current limited supply, with the utility procuring additional power

			Low	Medium	High
	Inputs	Annual evening load shedding %	14%	16%	19%
		Cost of peak power (Rs./kWh)	12	8	6
Rs./ year	**Components of willingness to pay**	Savings in kerosene expenditure (C)	80	140	330
		Interruption costs (C)	120	210	500
		Savings in kerosene subsidy (G)	120	120	390
		Net subsidy transfer (U/ urban consumers)	290	340	420
	Providing 50W supply instead of outright blackout	(Less) Unrecovered costs of peak power (U)	110	75	60
		(Less) Increase in electricity expenditure (R)	30	35	40
		Willingness to pay for current limiter	***470***	***700***	***1,500***

1. These are *annual* willingness to pay numbers borne by rural consumers (C), central government/ PSUs (G), and utility (U)
2. Kerosene consumption has been estimated bottom-up and these are very conservative (annual consumption of 3-13 liters)

Current limiters are viable if…

- Their installed costs are no more than

	Low	Medium	High
With 100 W supply	Rs. 2,000	Rs. 3,600	Rs. 8,900
With 50 W supply	Rs. 2,900	Rs. 4,300	Rs. 9,500

- Smart meters costing in the range of Rs. 4000 are already available in the market
  - Single phase static meters cost Rs. 800-1200 today
- This is for the “average rural feeder”
  - Some feeders are much worse than average- here, WTP will be much higher
- Note on assumptions
  - Supply (availability, costs) remains similar over the medium term (say, 10 years)

Summary

- High variances in supply availability among rural and urban feeders
  - Analysis of load shedding must be done at disaggregate levels and state-level estimates are not very useful barometers
- Rural domestic consumers provide a net “cross-subsidy” to domestic consumers in Bangalore
  - Non-Bangalore urban consumers in the BESCOM region provide subsidies through tariffs *and* load shed relief
- Providing current limited supply instead of outages seems to be preferable at current levels of load shedding
  - Costs can be offset by savings on kerosene expenditure and subsidies
  - The case for these becomes stronger as load shedding is higher

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