

**ELECTRICITY MARKETS IN A
CARBON-CONSTRAINED WORLD:
REFORMING SCHEDULING
PRACTICES IN CHINA AND INDIA**

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Electricity markets: past, present and future

- Majority of OECD and over 70 non-OECD countries have reformed vertically-integrated utilities, incl some / all of:
 - Unbundled and competitive generation companies
 - Wholesale spot markets for real-time balancing
 - Unbundled and competitive retail companies
 - Cost-based / incentive regulation for grid monopolies
 - Independent regulator
- Spot markets essential to “standard” model:
 - Fine time and geographic granularity matches various needs
 - Well-designed spot markets create incentives for flexibility and naturally prioritize renewable energy
- Some adjustments to accommodate higher RE
 - E.g., flexibility products, dynamic reserves, capacity value..
 - (Assume well-functioning standard spot market)
 - In very-high RE system, marginal costs may need to be revisited

(Hunt, 2002; Joskow, 2008; Neuhoff, Wolter, & Schwenen, 2016; Conejo & Sioshansi, 2018)

Diverging from the “standard model”

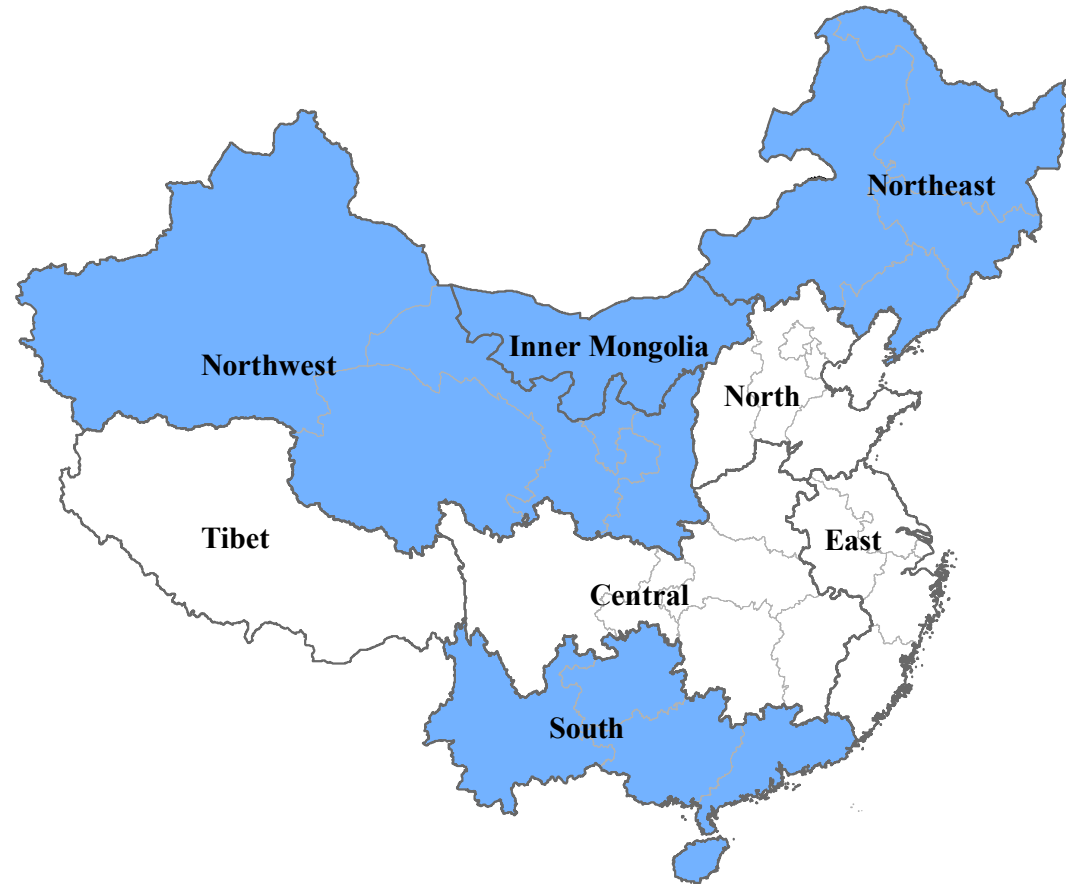
- Country motivations for reform are varied:
 - Efficiency
 - Customer choice
 - Private finance
 - Reliability
- ...and implementation frequently diverges from model:
 - Legacy gov’t planning institutions distort markets
 - Non-standard market designs
 - Uneven implementation, political favoritism, non-independent regulator...
- Aggregate panel data show price and cost changes sensitive to degrees of institutional development
- Regional integration studies examine benefits of coupling (standard) markets
- **Few studies have investigated effects of transitional, non-standard markets on scheduling and dispatch**

(Williams & Ghanadan, 2006; Jamasb, Nepal, & Timilsina, 2017; Neuhoff, Wolter, & Schwenen, 2016)

CHINA

Data

- Provincial case studies
 - Diversity of systems & market experiments
- 66 interviews (2015-2016) plus several scoping visits
 - Government (central + local)
 - Grid (central + reg'l + local)
 - Research (academic + grid-affiliated)
- Archival materials (gov't and grid reports, media accounts)
- See my dissertation (2018) for full results



China's rounds of power sector reforms

1949-1985: Vertically-integrated state-run utility

- Centralized investment & planning → State finances limited

1985 (**Round 1**): Open investment in generation

- Local gov't, private & foreign investors “competed” with bundled ministry owned generation → Inefficient plan allocation

1997-2002 (**Round 2**): Corporatization and unbundling

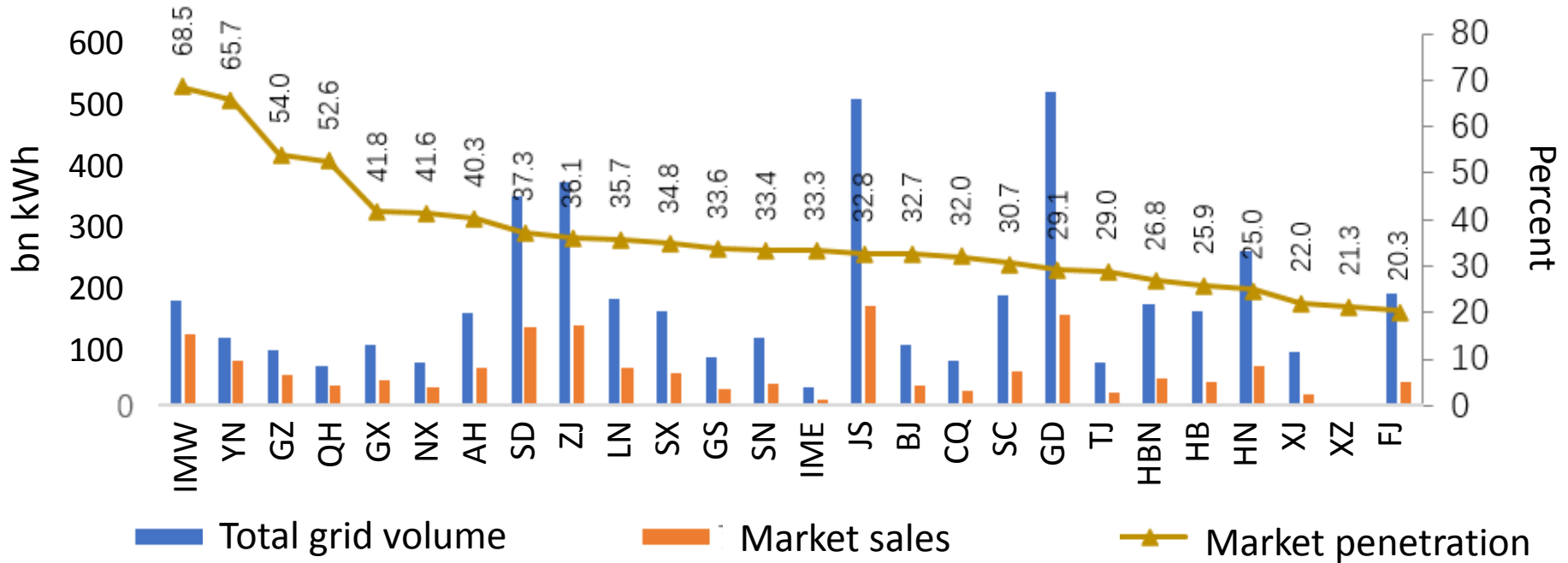
- Separate grid & generation → Lacks competition (“equal shares”)
→ Inefficient grid cost regulation (“difference tariffs”)
- Generation market pilots failed → Local gov'ts prevent regionalism
- Independent regulator (until 2014) → Lacks authority and independence

2015- (**Round 3**): Provincial market experimentation

- Convert planned quotas to competitive contracts
- “Relatively independent” exchanges
- Regulated cost-of-service T&D services

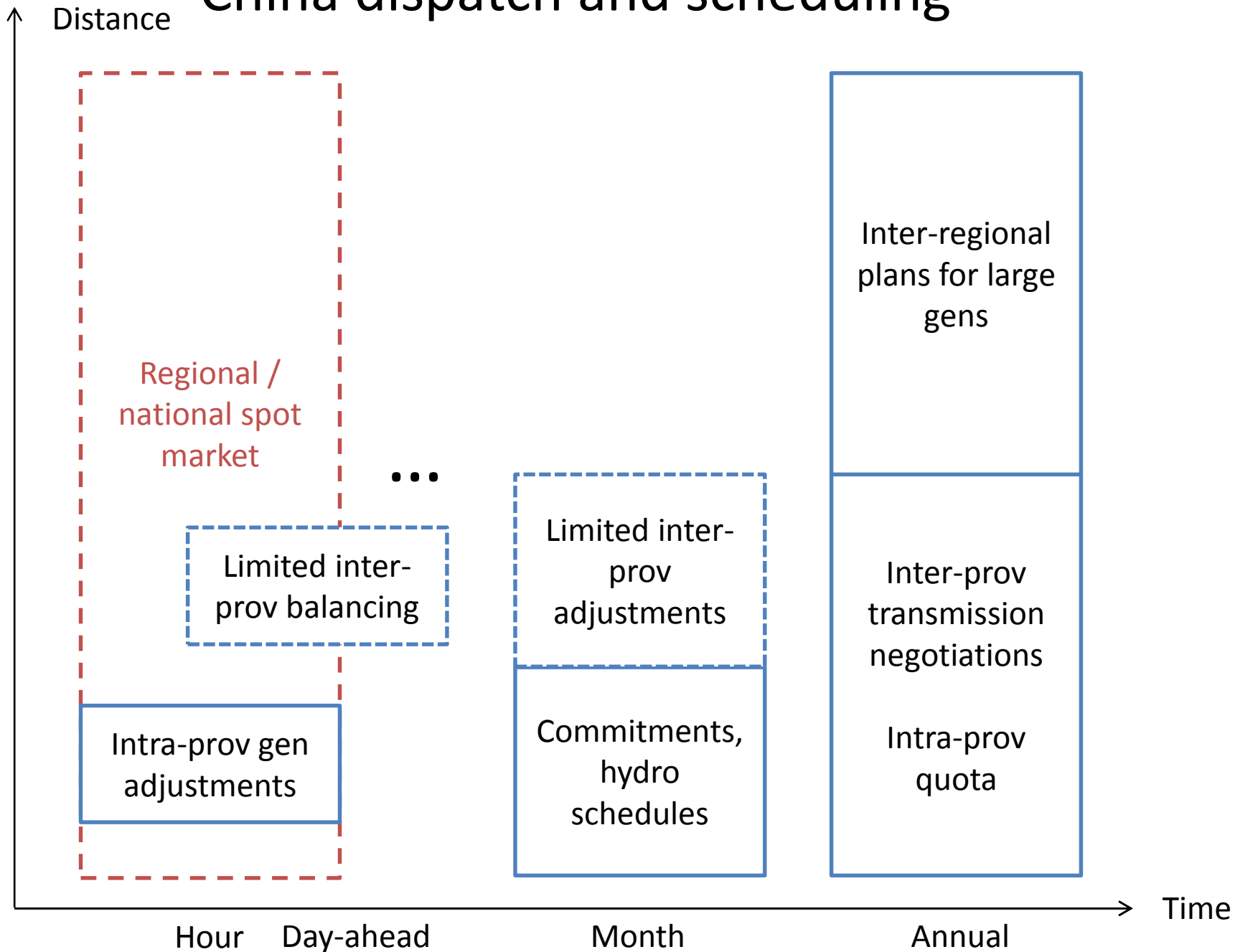
(NEA; Andrews-Speed 2013; Zhang & Heller 2007; State Council, 2015)

Power market penetration, 2017H1

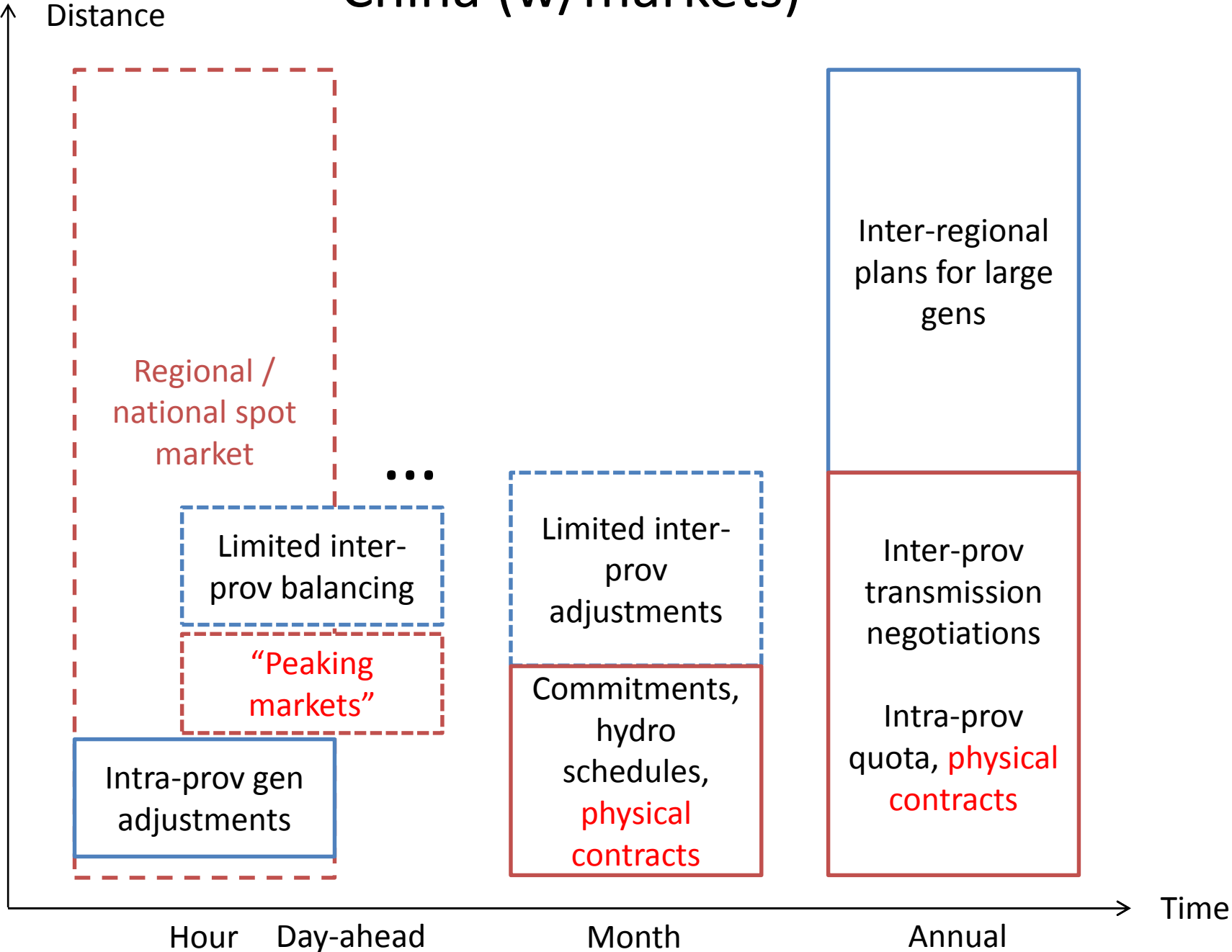


(CEC, 2018)

China dispatch and scheduling



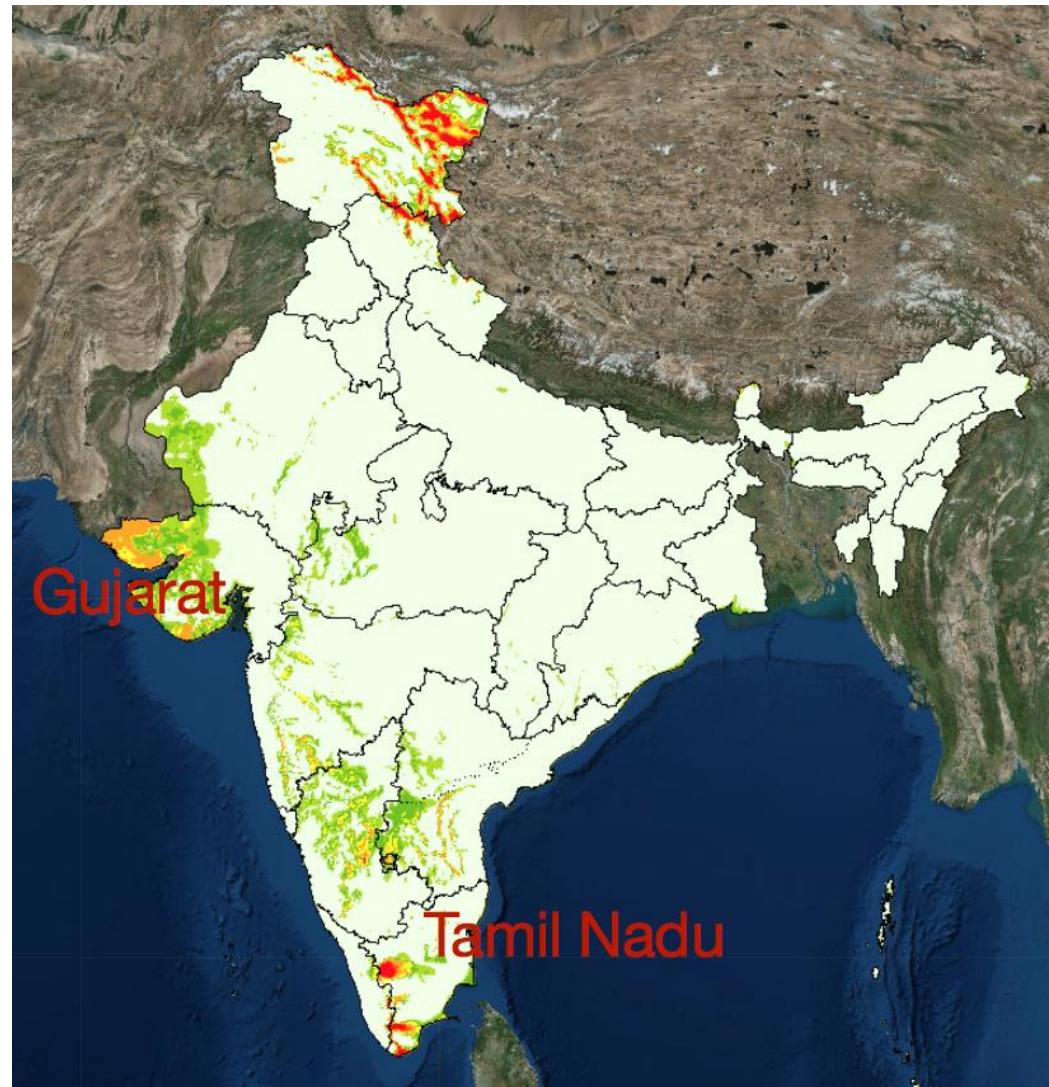
China (w/markets)



INDIA

Data

- Two state case studies
 - High RE and flexibility challenges
 - Range of perceived sophistication of operation, discom health
- 34 interviews (2017) plus 1 day of observation
 - Gov't & regulators (central + state)
 - Grid operators (central + state)
 - RE companies
 - Research (academic + grid-affiliated)



India's power market evolution

Pre-1991: vertically-integrated State Electricity Boards

1990s: Open investment to private and foreign IPPs

- Guaranteed rates of return, expensive
- Some state-level regulatory commissions

2003: Electricity Act to create all-India competitive market

- Formally launched unbundling:
SEBs → Gencos, Load dispatch centers, Distribution companies
- But, only nominally unbundled in some states (e.g., subsidiaries of former SEB)
- State regulatory commissions

2005-: National Electricity Policy and Tariff Policies

- Formalize bidding process
- Preference for long-term contracts (e.g., coal = 25 years)
- Two-part tariffs (Availability Based Tariff)

2010: Power market regulations

- National power exchanges

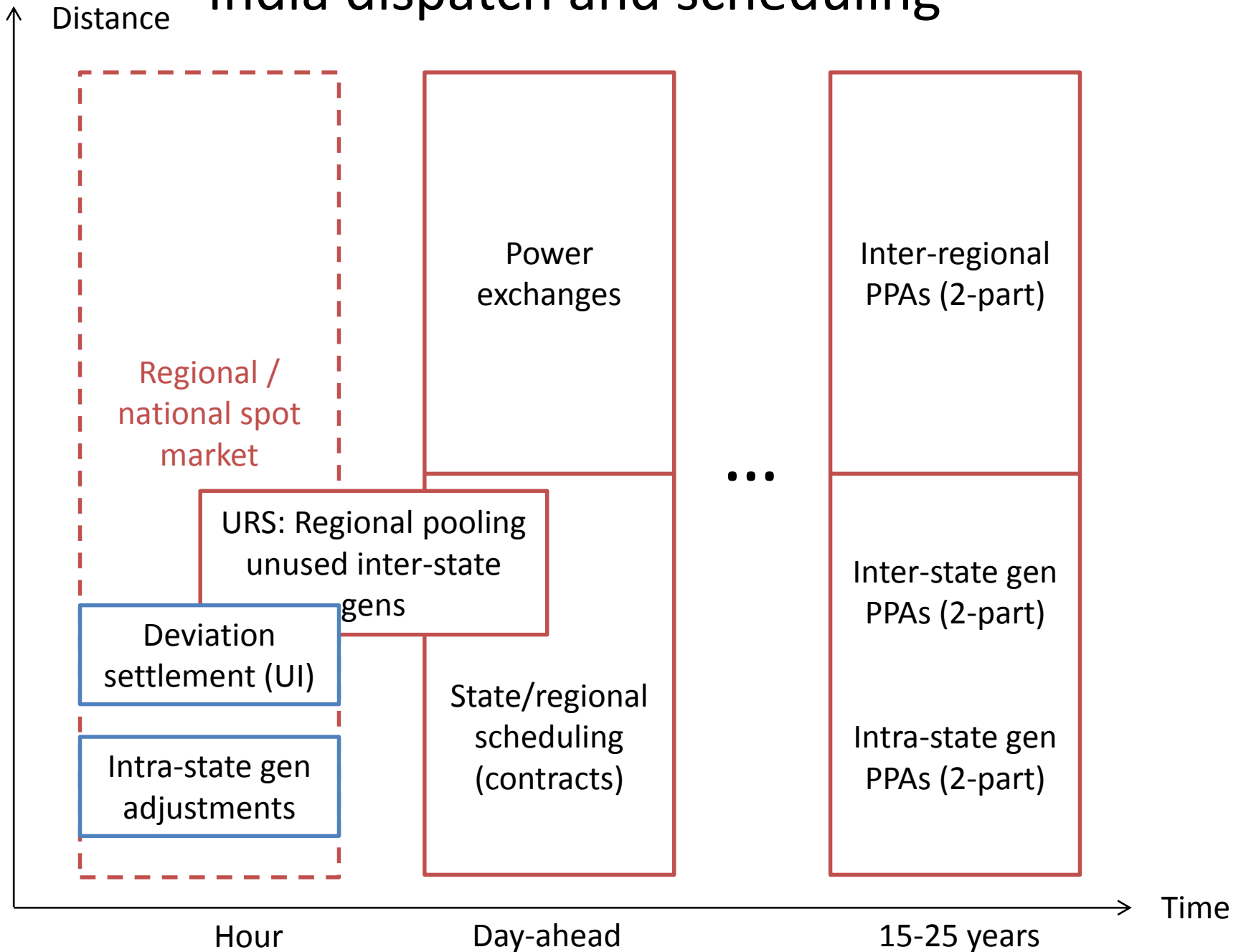
(Kumar and Chatterjee 2012; Tongia 2007; Government of India, 2005; CERC, 2017)

Market size

Transaction	Share of generation
Long-term PPAs	~90%
Short-term (< 1 year) contracts	10%
...Bilateral: traders	3%
...Bilateral: discom-discom	2%
...Power exchange: day-ahead	3%
...Power exchange: intra-day	0.08%
...Deviation settlement / UI	2%

(CERC, 2017)

India dispatch and scheduling



DISCUSSION

Partial liberalization effects on flexibility

- Both have medium- to long-term physical obligations that dominate total energy transactions
- Distortions of short-run dispatch
 - India: 2-part tariffs in merit order
 - China: inflexible quota/contract allocation
- Different operations, markets and regulations at state, regional and national levels
 - Longer distance less flexible at short time intervals
- Different treatment of conventional vs. RE
 - India: e.g., long-term contracts
 - China: e.g., monthly scheduling
- Potential for grid operator conflicts of interest
 - India: incomplete unbundling
 - China: revenue structure

Research on restructuring for decarbonization

- More qualitative work is needed
 - Evaluate *de facto* institutions of regulation (beyond binary indicators)
 - Disaggregate scheduling & dispatch practices
- Quantitative models moving beyond ideal assumptions
 - Analyze legacy institutions, non-standard markets... interactions w/RE characteristics
 - Ex: Davidson & Pérez-Arriaga (2018): institutional causes of wind curtailment in China
- New formulations and solution techniques
 - Formulating dispatch heuristics and complex contract structures
 - Sensitivities around uncertain / unobservable political parameters require computational efficiency
 - Long-term political constraints: coupling challenges across long time horizons (cf planning models w/operational detail)

Policy recommendations

For long-term structural reforms for efficient, low-carbon market operations:

1. Increase centralization of market design and oversight
2. Establish consistent policy for transition costs
3. Rely more strongly on financial vs. physical contracts
4. Establish/strengthen short-term markets

Medium-term policies:

1. Central planning and control over investments: e.g., reduce/eliminate new coal plant permitting in China
2. Adjust RE support policies: e.g., tariffs to incorporate integration costs
3. Expand sub-national market coupling
4. Establish reserve accounting and sharing mechanisms

THANK YOU.

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India dispatch (detailed)

Day-ahead:

- 1000: All generators declare available capacity for next day (15-min blocks) to State Load Dispatch Center (SLDC), Regional Load Dispatch Center (RLDC)
- 1000-1100: Gujarat: SLDC will help state-owned discoms (GUNL) with identifying exchange purchases
- 1100-1700: Exchange
- 1500: SLDC sends schedule to RLDC
- 1700: RLDC confirms schedule w/SLDC
- 1800: SLDC notifies generators day-ahead schedule (Tamil Nadu: up to 2400, can revise schedule)

Real-time principles:

- Seek to minimize Unscheduled Interchange (UI) according to frequency deviations
- Once day starts, will incur first-part fixed cost tariff
- Schedule generators acc “merit order” (variable costs in contract, or exchange)
- More commonly...“back down” plants according to reverse MO
- RE is supposed to be “must-run”, meaning it should not be considered in MO

Real-time timing:

- 2.5-1.5 hour ahead (ha): intra-day exchange (extremely small)
- 1.5 ha: normal changes to schedule
- 1-0.5 ha: Un-Requisitioned Surplus (URS): regional pooling of inter-state generators’ excess capacity, SLDC can view and purchase in MO
- 0.5 ha: SLDC notifies intra-state generators of backing down