Long-Term Renewable Energy Integration Planning in India: Challenges and Opportunities

Partha Das*, Jyotirmay Mathur*, Rohit Bhakar*, Amit Kanudia†

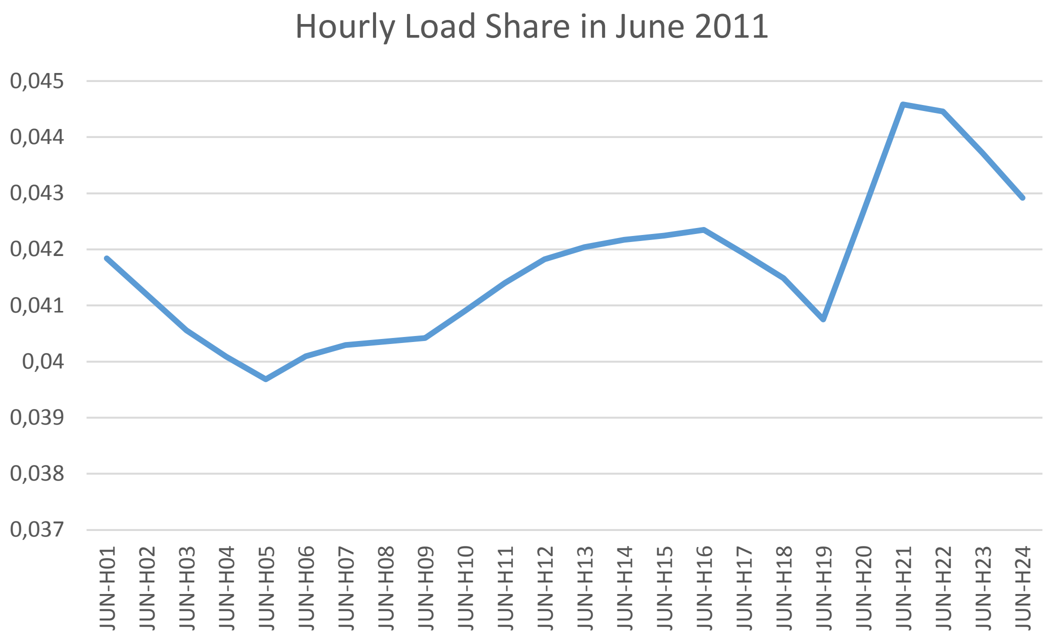
*Centre for Energy and Environment
Malaviya National Institute of Technology Jaipur, Rajasthan-302017, India

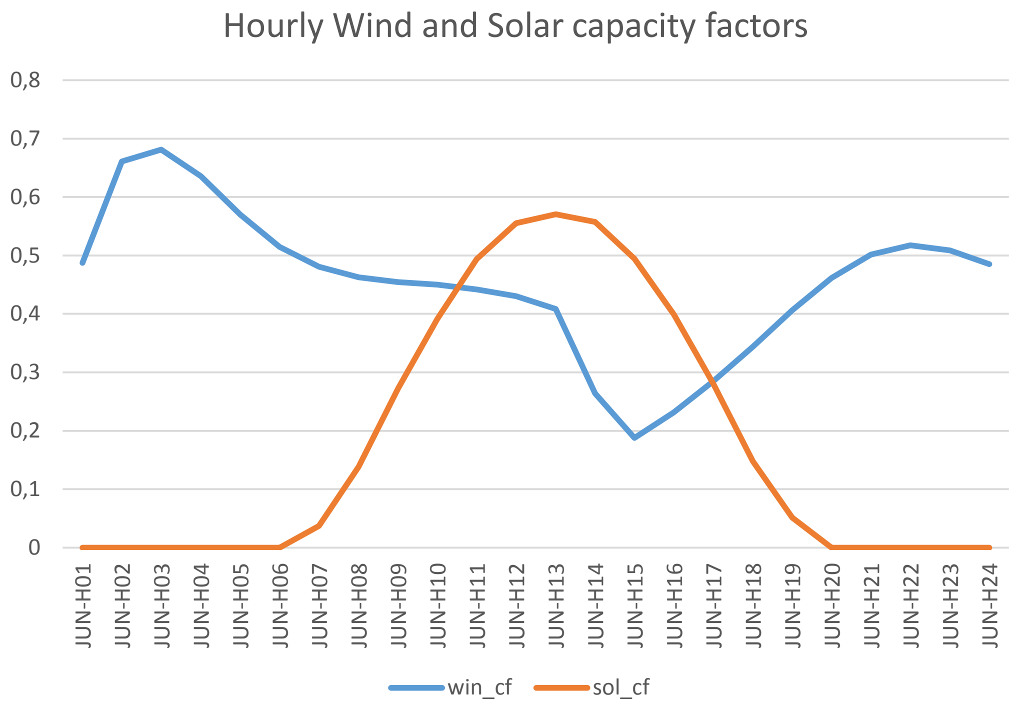
†KanORS-EMR
NSEZ, Noida, Uttar Pradesh-201305, India

Background: India’s Focus on Solar and Wind

- 20-25% emission reduction per unit of GDP by 2020 from 2005 level.
- 33-35% percent less emission intensity per unit GDP by 2030, compared to 2005 level.
- Affordable, reliable, and sustainable electricity to all households by 2019 under se4all.
- 40% cumulative non-fossil fuel-based electric power generating capacity by 2030 .
- Massive Solar Power Push’ scheme of MNRE: 175GW of RE capacity by 2022 (100 GW solar, 60 GW wind).
- 8% of electricity consumption from solar energy by 2022.

Operational Challenges with Large-Scale RE Integration





Hourly load share India in June 2011, Hourly wind and solar capacity factor for a random location in Rajasthan

Operational Challenges with Large-Scale RE Integration

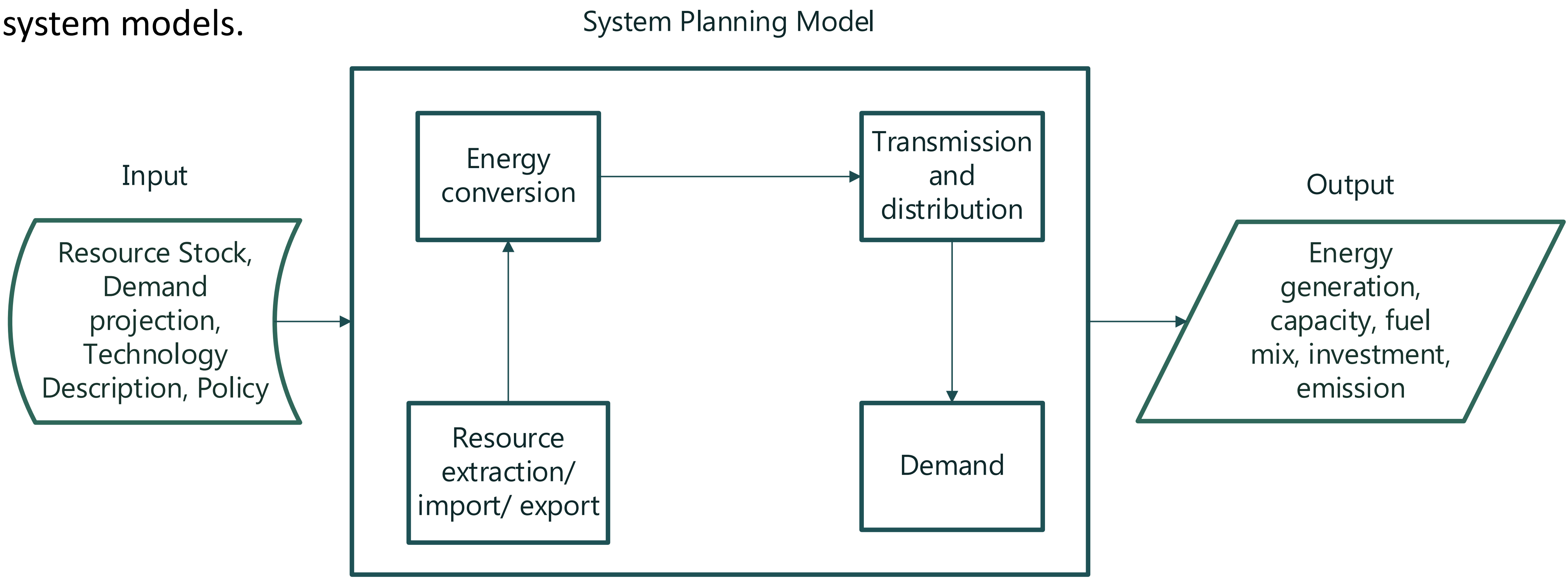
- Temporal intermittency: Supply uncorrelated with demand creating power management related challenges.
- Uncertainty of output: Scheduling and balancing related challenges, as actual RE generation deviates from forecasts.
- location specificity: localized grid congestion during sudden RE generation inrush.
- System Inflexibility: Operational constraints on thermal generators.
- RE Curtailment: Decreases capacity factor, increases payback time, difficulty meeting greenhouse gas emission targets.

Challenges with RE Integration Planning

- Location specificity of RE resources requires developing huge new transmission corridors.
- They often are underutilized due to natural RE variability or generation curtailment.
- Difference of lead time between transmission line and RE capacity can cause generation curtailment.
- Flexibility adequacy need to be planned several years ahead.
- Flexibility options i.e. storage, DSM etc. differs with techno-economic policy scenarios.

Long-Term System Planning Approaches in India

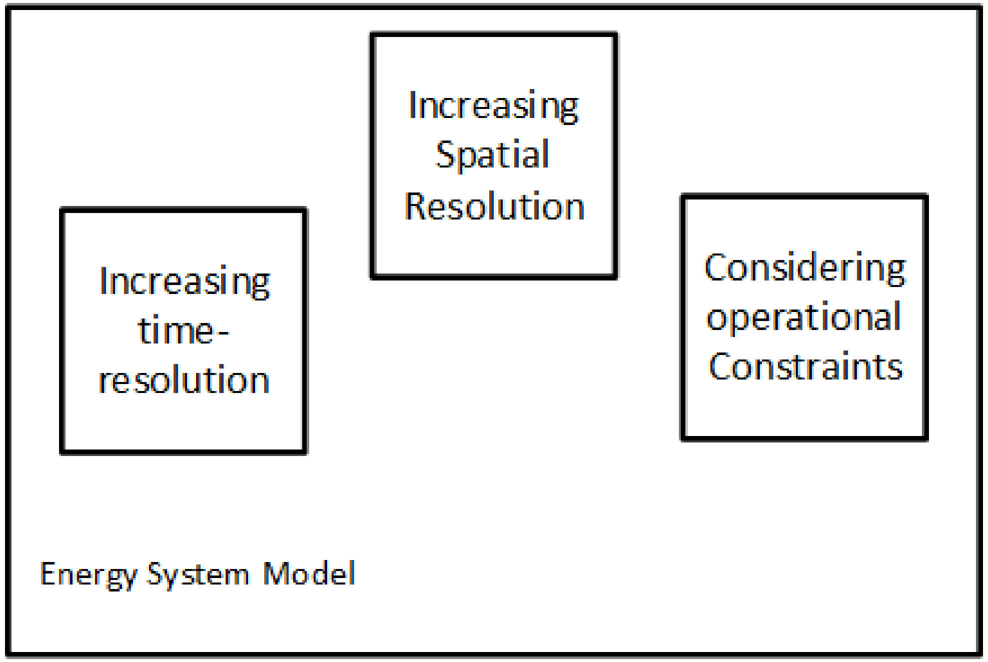
- Resource optimization models.
- Macro-economic models
- Energy system models.



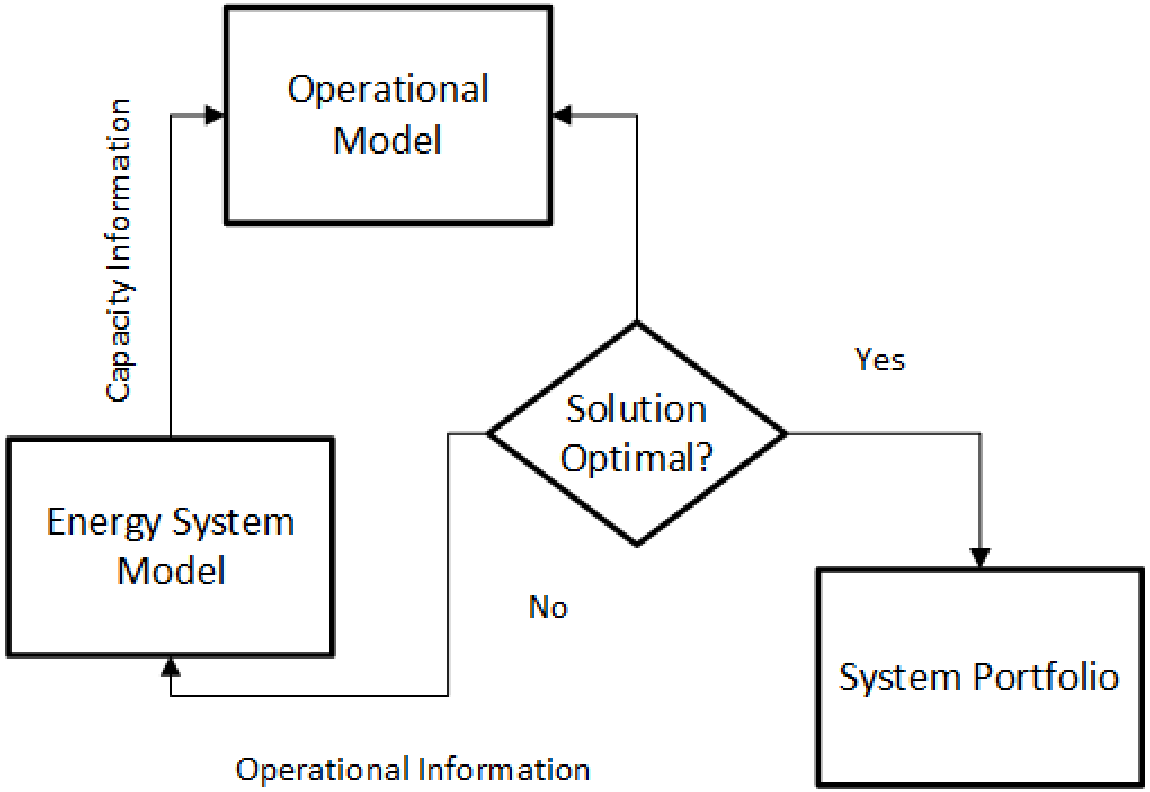
Need of revising the planning approaches

- Simplified temporal and spatial definitions: do not consider short-term resource variation.
- Do not track the effect of spatial or temporal variation of RE resource on power flow and network congestion.
- Focus on resource adequacy, ignores the quality of the system components.
- Identify chronological investment decision over a long-term horizon, do not optimize generator scheduling or dispatch.
- Representation of operational constraints is often ignored or oversimplified.
- System portfolio reported are often unrealistic and unreliable.

Approaches for Methodological Improvement



Endogenous Modelling Improvement



Exogenous Modelling Improvement

Comparison of Approaches for Methodological Improvement

Endogenous Modelling Improvement

- Higher number of annual time slices, model regions.
- Additional computational burden and design complexity.
- Improving single methodological aspect does not provide additional benefit.
- operational constraints are stylized.

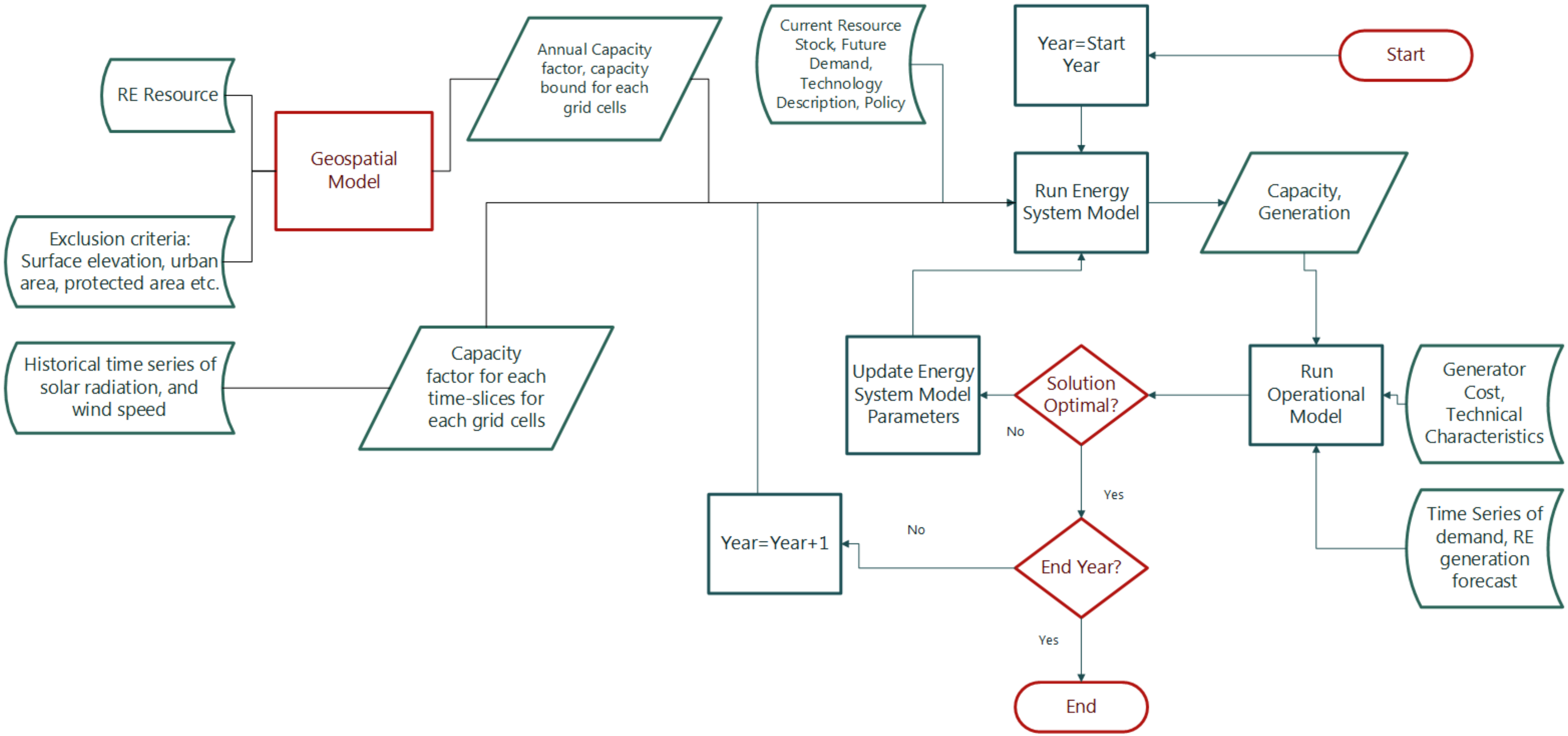
Exogenous Modelling Improvement

- Multiple models/ tools linked together to achieve a common goal
- Utilizes the strengths of individual models/ tools avoiding unnecessary burden to a single one.
- Scheduling and dispatch models are used to optimize system operation.
- Challenging to establish a proper route of data transfer and select the converging criteria

Proposed Integrated Approach

- Regional definitions of models are mainly driven by the political or economic boundary, rather than resource variations.
- Consideration of large number of model regions is often prohibitive.
- Planning models often utilize single annual capacity factor of a technology per region to calculate yearly generation as well as capacity requirement.
- It ignores the spatial as well as temporal variation of RE resource intensity.
- Such coarse representation of RE variability cannot complement the operational model used in hybrid modelling approaches

Block Diagram of Overall Approach

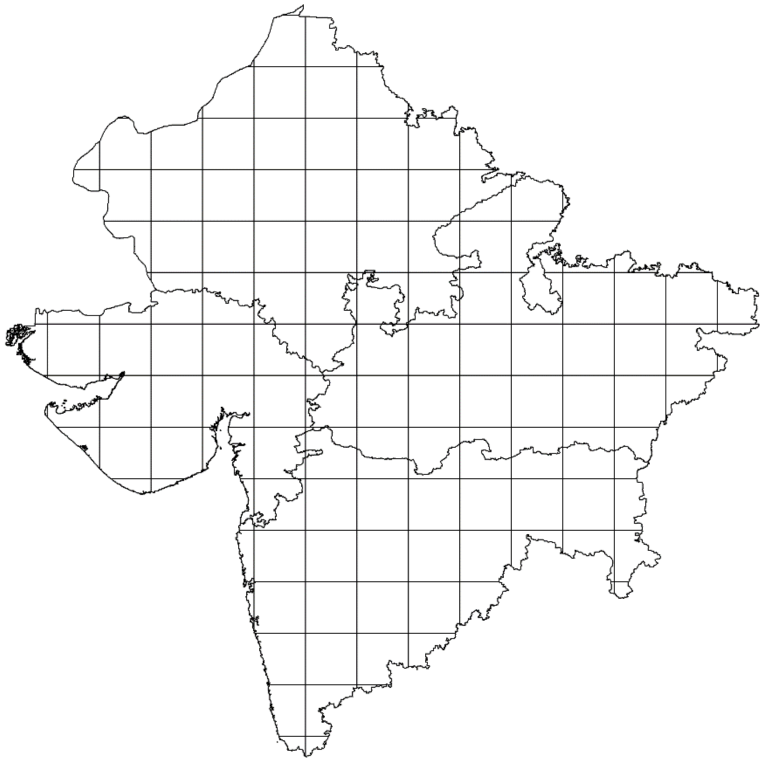


Steps of the Proposed Approach

- Divide each model region into geographical grid-cells (1-degree by 1-degree in this case).
- Utilize GIS to derive high-resolution annual capacity factor and the capacity potential for each grid cell considering resource intensity and land suitability.
- Utilize historical hourly time series of wind speed and solar radiation of each grid cells to calculate capacity factor for each model time slices.
- Represent each grid cell as a different technology with its own annual capacity factor, capacity bound, and time-slice specific capacity factors.
- Couple the model with a dedicated power system dispatch model similar to the exogenous approach.

Application of GIS in Proposed Approach

Model Regions



Model Regions divided into grid-cells

Utility of the Proposed Approach

- Endogenously improves the representation of RE variability in the system model.
- Compared to a traditional hybrid approach, it can provide better capacity information to the operational model.
- Openly available GIS data layers and tools can be utilized to achieve this task.
- Can provide better information of future RE investment need including its location.
- Role of flexible resources e.g. storage, network expansion in future RE penetration scenarios, can be better analyzed.

Final Thoughts

- The approach outlined is an attempt to bridge the gap between short-term operation and long-term planning.
- Increased coordination between different planning agencies and operational utilities.
- Improved tools, algorithms, advanced data maintenance and management practices.
- Increased availability of data, computational resource, and trained manpower for model development and maintenance.

Thank You