Rumi/PIER: An open-source bottom-up demand-oriented energy systems model

Prayas (Energy Group)

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Outline

- Energy transition and the role of open energy modelling
- Energy systems modelling platform: Rumi
- India energy model based on Rumi: PIER
- Future Plans

Transition in the Indian Energy Sector

- Transition at the door, pulls and pushes in different directions

- Drivers
  - Technoeconomic: Renewables, Storage, Grid management, End-use efficiency, Demand response
  - Social and ecological: Local environmental impacts, Climate mitigation, Natural resource limitations
  - Increasing electrification of the economy (especially industry, transport), New energy sources such as hydrogen
  - Changing business models: Markets, prosumers, digitalisation …
  - Government policies and programs, International obligations

- Modelling can help provide critical inputs to prepare for a fair transition

Model Objectives

- Objectives
  - Enable modelling and analysis relevant to policy and planning
  - Transparent, open source energy modelling platform (python/pyomo)
  - Should be possible to link to other models to further enrich analysis

- Energy System Model
  - Capture linkages between energy sector and rest of the economy

- Demand focused
  - Enable detailed bottom-up energy service oriented modelling
  - Spatial / temporal / consumer-type disaggregation

Rumi – Energy Systems Modelling Platform

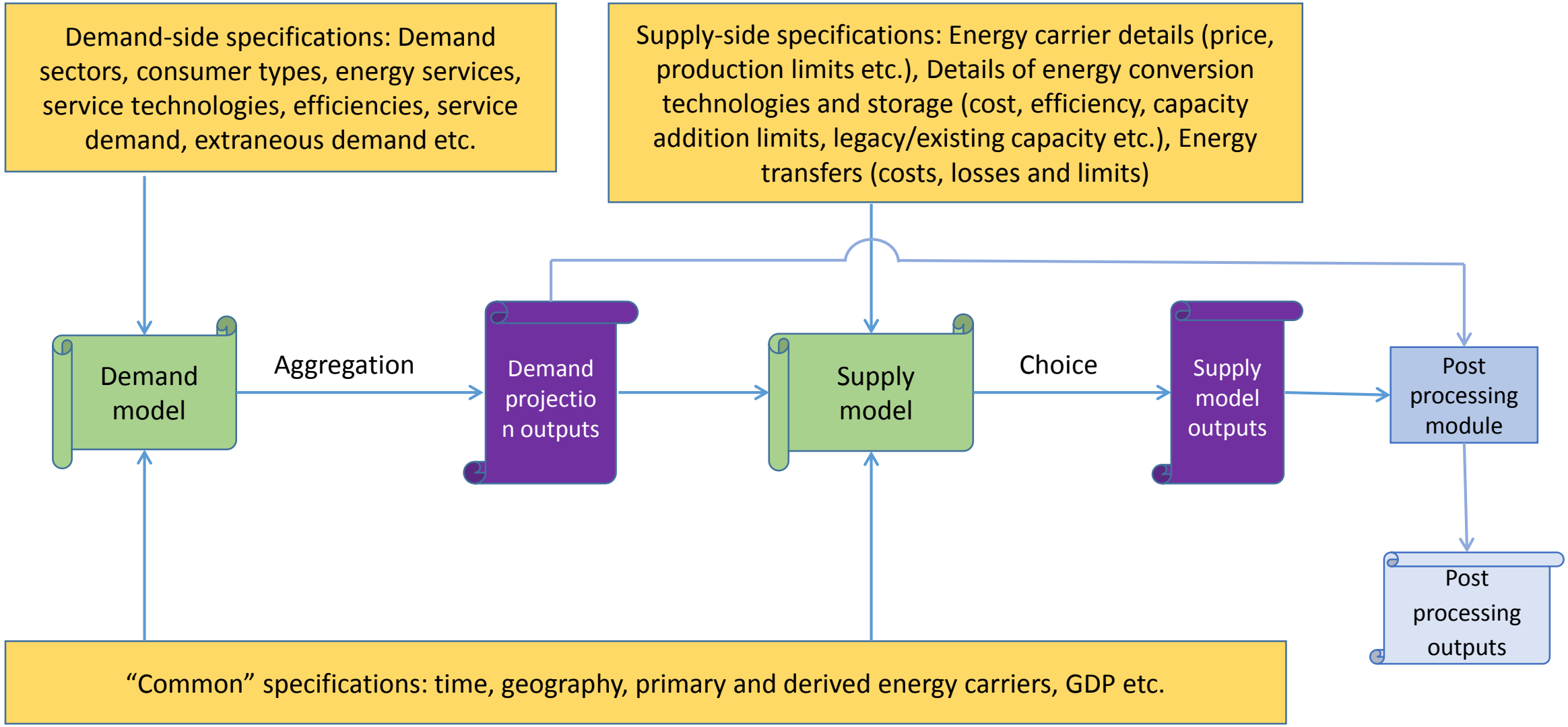
Why Rumi?

- To build models to answer interesting questions about India's energy sector
  - Impacts of policy signals (e.g. taxes, subsidies, incentives, mandates)
  - Impacts of changes in norms (e.g. consumer behaviour, urban form, ESG …)
  - Impacts in terms of supply and demand mixes
  - Impacts in terms of costs, geographic distribution, emissions etc.

- Generic
  - Geographic and temporal scope and granularity
  - The energy carriers to model and their characteristics
  - The energy conversion technologies to model

- PIER: Complete India model with all relevant data available for reference or direct use

Rumi architecture



Building a Rumi model

Building a Rumi model involves defining the following:

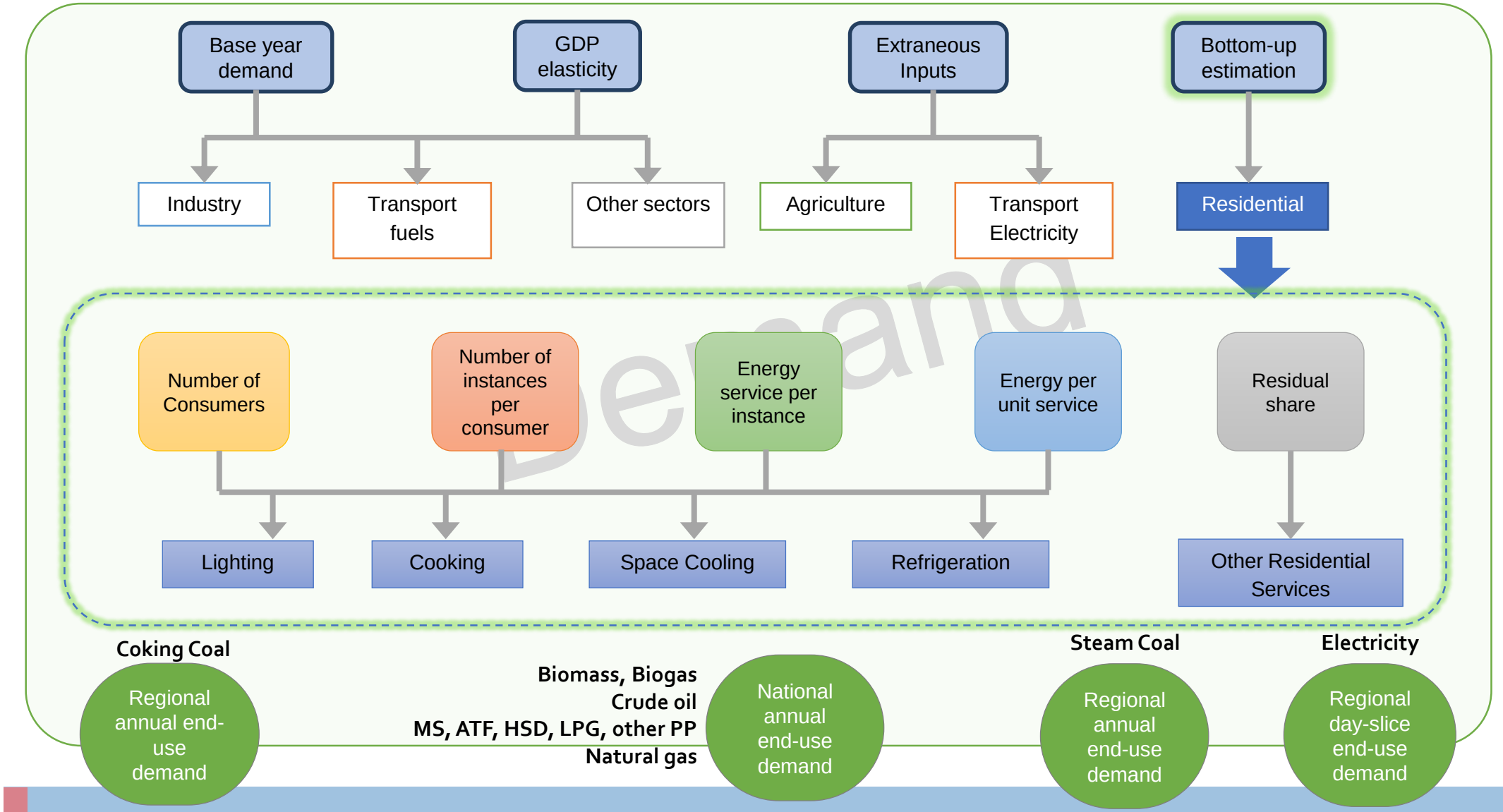
- The geographic and temporal scope of the model
  - With up to four levels of disaggregation
- The energy carriers being modelled
- Energy demand
  - Energy demand sectors
  - Energy services
  - Technologies providing the services and their details
  - Demand can also be specified exogenously or as GDP elasticity
- Energy supply
  - Costs, production limits, conversion and storage technology characteristics
  - Energy transfer limits, losses and costs
- Computes demand and finds cost-optimal supply mix to meet demand

PIER – Perspectives on Indian Energy based on Rumi

PIER: Perspectives on Indian Energy based on Rumi

- India modelled as 5 regions and 25 “states”
- Model horizon year 2030-31
  - Each year consisting of 5 seasons
  - Each season consisting of one typical day of six ‘day slices’ (electricity)
- Energy carriers modelled
  - Steam coal, coking coal, crude oil, natural gas, biomass, biogas
  - Petroleum products (MS, HSD, ATF, LPG, Others), Electricity
- Five demand sectors modelled (Residential, Industry, Transport, Agriculture, Others)
- Residential consumers modelled as 250 types (state, urban/rural, quintiles)
- Nine electricity generation technologies modelled (Coal, OCGT, CCGT, nuclear, large hydro, small hydro, biomass, solar, wind)

PIER: Demand model



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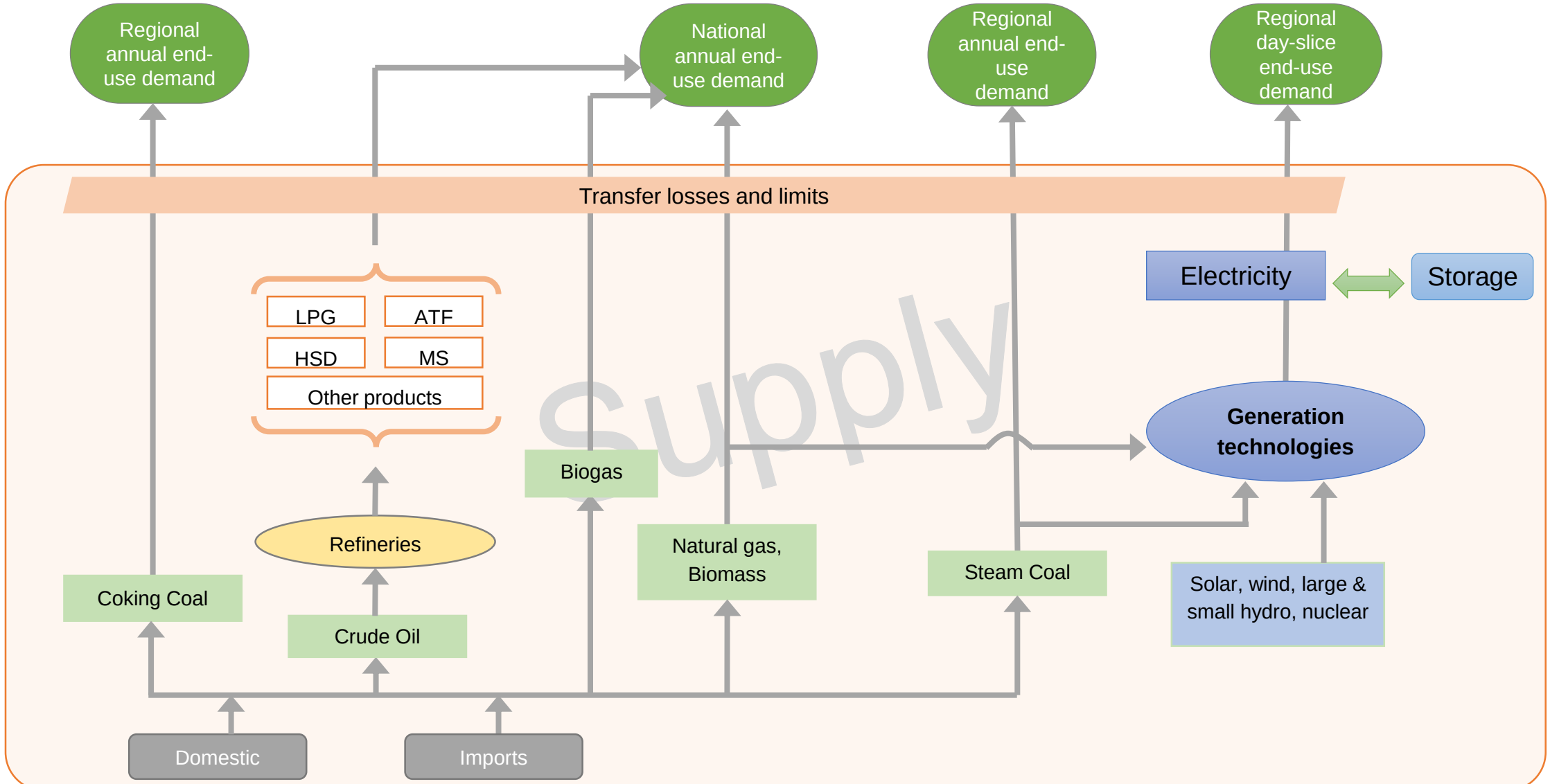
PIER: Supply model



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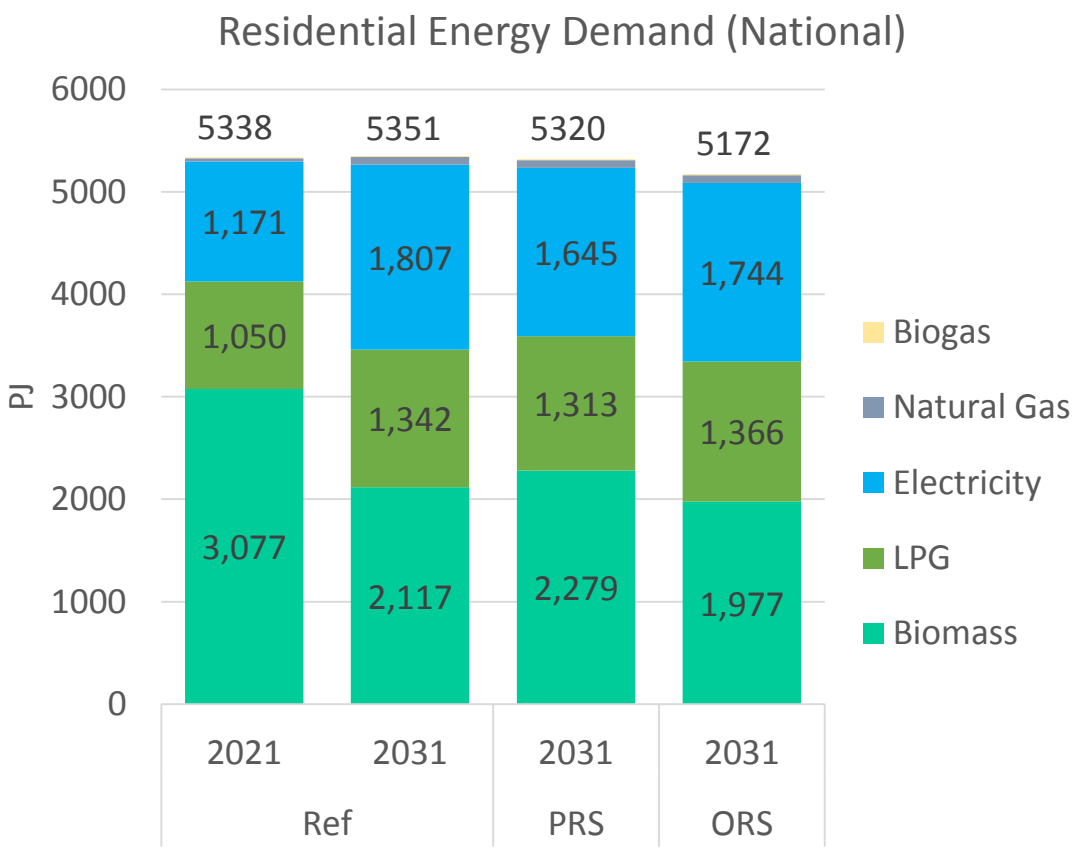
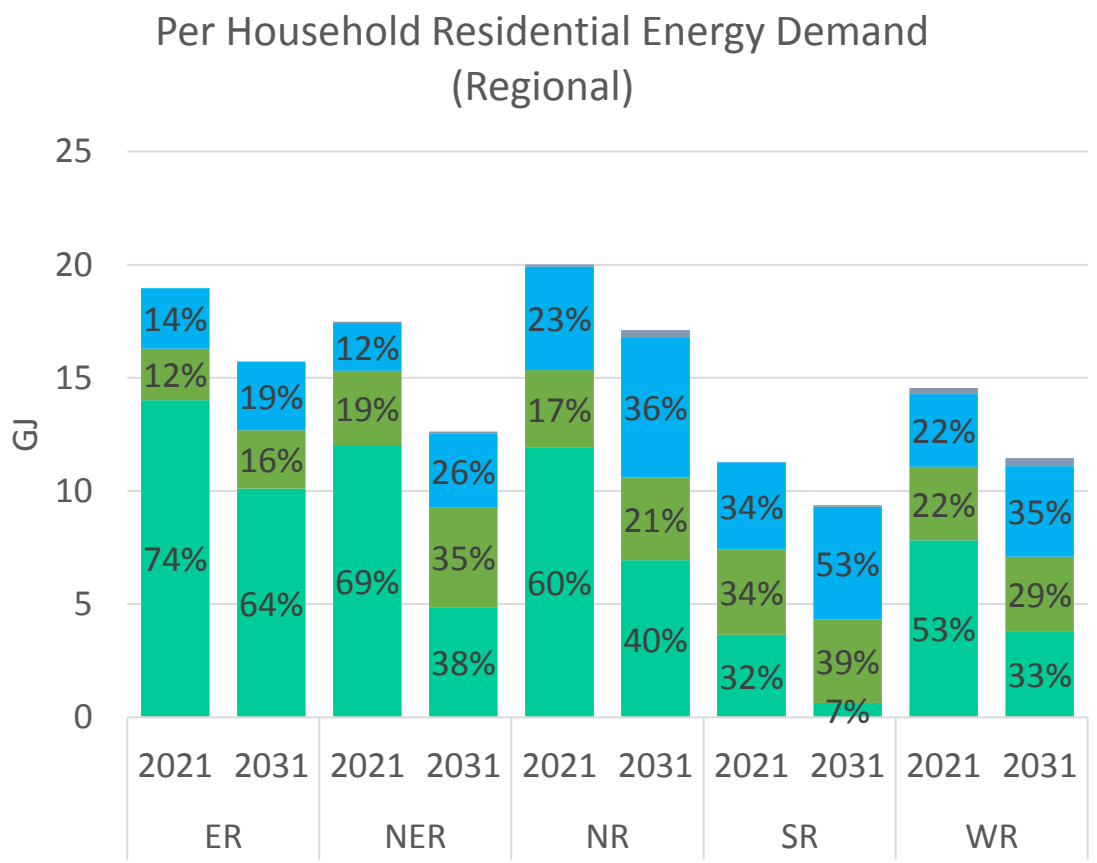
Insight 1: Use of modern cooking fuels needs attention

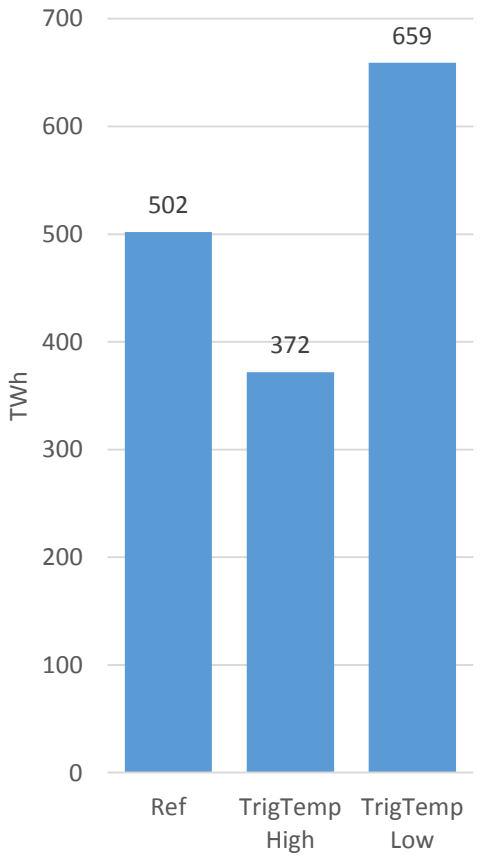




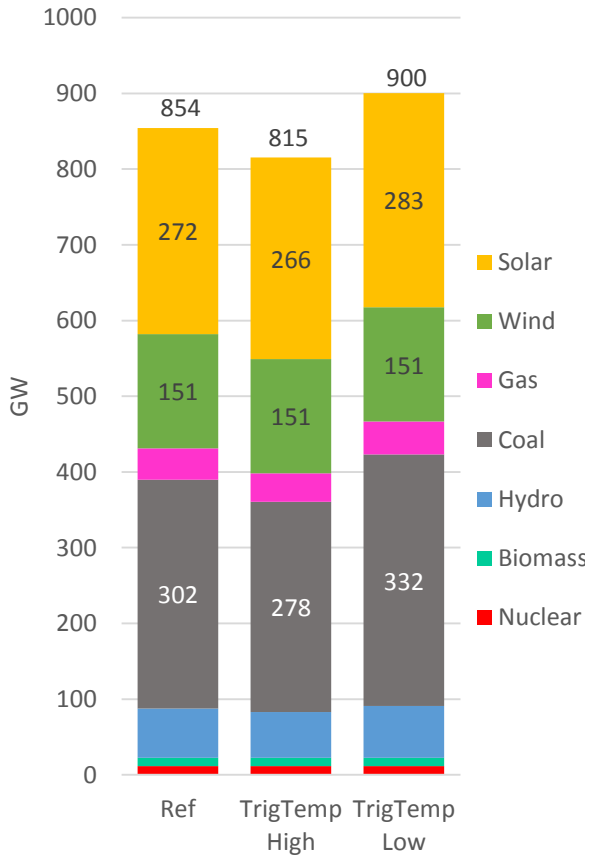
- A challenge even in FY31: ~40% of residential energy from solid fuels (biomass)
- Particularly in ER: ~64% from solid fuels; SR relatively good, only ~7%

Insight 2: Role of consumer behaviour (and efficiency)

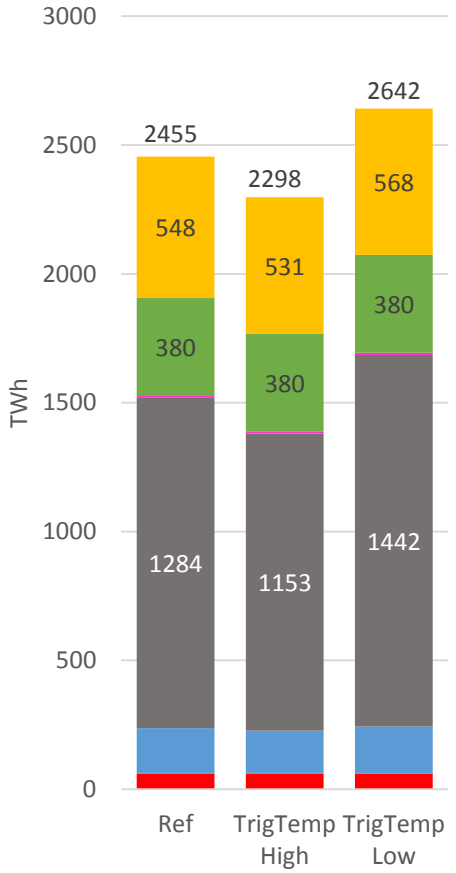
Residential Electricity Demand (FY31)



Electricity Generation Capacity (FY31)



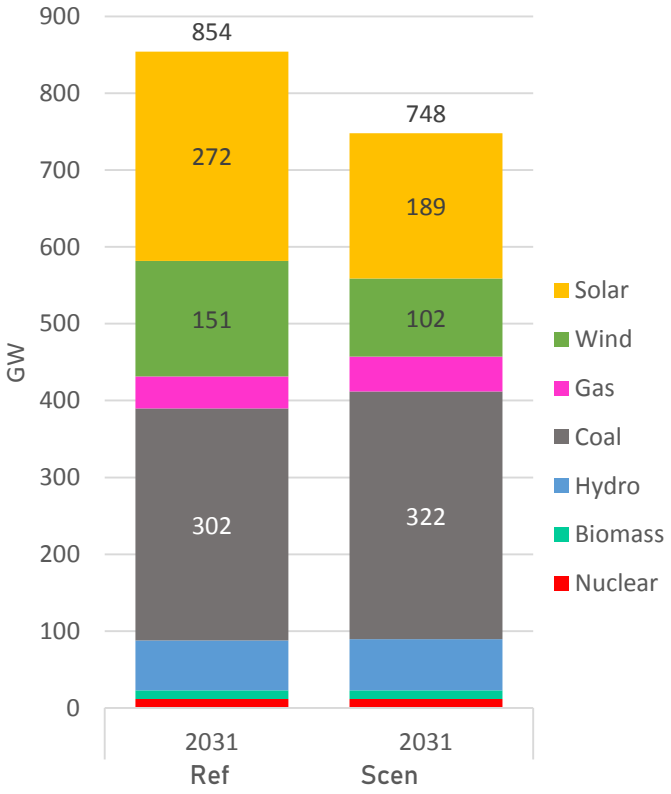
Electricity Generation (FY31)

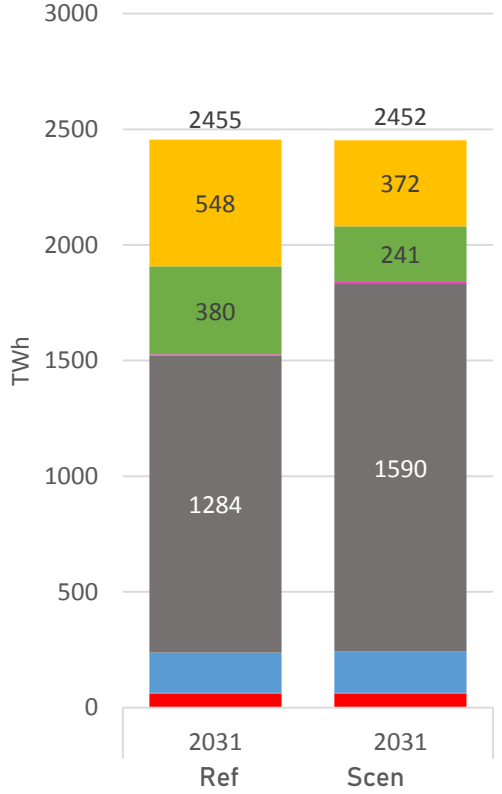


- Big impact on electricity demand, supply mix due to difference of 2°C in using cooling appliances
- 130-150 TWh difference in electricity demand
- 24-30 GW difference in installed coal capacity
- Efficiency also has a similar effect

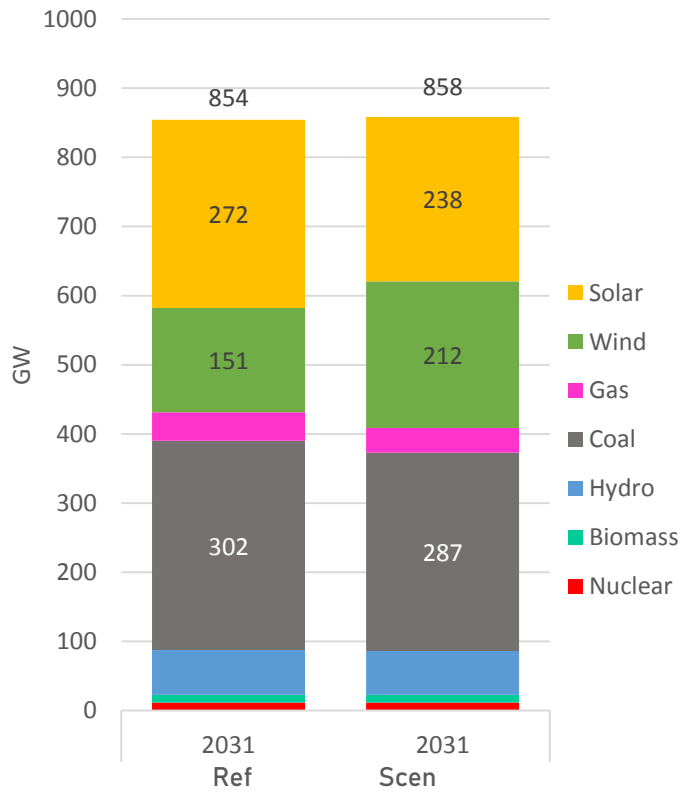
Insight 3: Effects of different RE addition scenarios

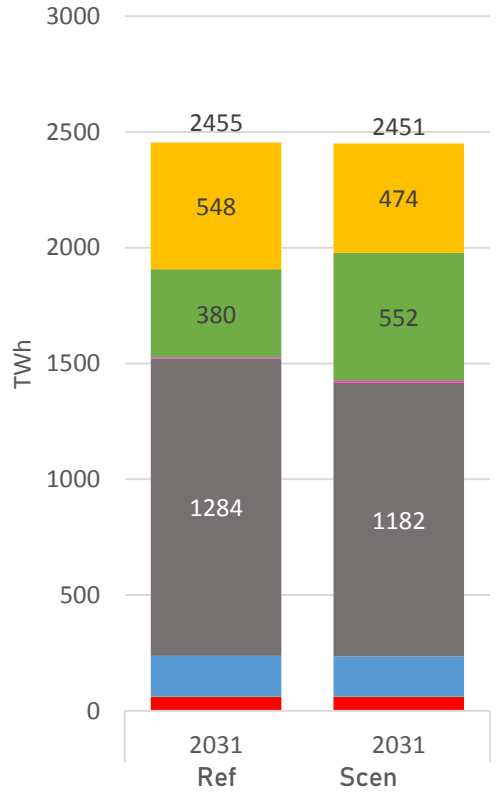
LowerSolarWind





EqualSolarWind





- If requisite pace of RE addition not maintained, coal becomes the back-stop
- Equal prioritization of solar and wind can reduce dependence on coal for little extra cost

Current limitations and plans

- Current limitations
  - Rumi
    - Demand and supply independent, e.g., price elasticity of demand → dependence needs to be modelled exogenously
    - Only primary energy carriers can be imported; exports not supported
    - Energy technologies work off only one energy carrier to provide one energy service or one energy carrier
  - PIER
    - Bottom-up demand estimation limited to residential sector
- Plans
  - Address some of the limitations
  - Extend bottom-up demand modelling in PIER to transport and industry sectors
  - Extend time horizon beyond 2030
  - Explore soft-linking complementary models, e.g., a macroeconomic model, to study a wider range of issues

Conclusions

- Models increasingly needed/required to inform policy and regulatory questions
- Rumi / PIER likely to be useful for ongoing / proposed research work
- Designed as open-source and open-data in order to be useful for academic and research exercises
  - PEG can provide knowledge sharing support as needed

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https://bit.ly/PEGnewsletter

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Report: https://www.prayaspune.org/peg/publications/item/512

Git Repos:

Rumi: https://github.com/prayas-energy/rumi

PIER: https://github.com/prayas-energy/PIER

Email us at energy.model@prayaspune.org

THANK YOU