An Evaluation of Food-Energy-Water Nexus Footprint: Case of Pune District in Maharashtra, India

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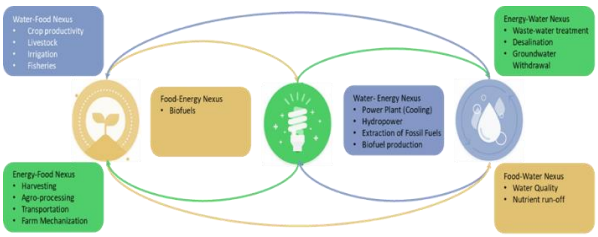
Background: The unrestrained flow of Food-Energy-Water (FEW) resources is pivotal for ensuring sustained economic development and societal well-being and its significance can be derived from the Sustainable Development Goals (SDGs) of 'Zero Hunger' (Goal 2), "Clean Water and Sanitation" (Goal 6) and 'Affordable and Clean Energy' (Goal 7). The constraints on the provision of FEW resources in recent years are largely attributed to an exponential increase in demand accompanied by supply-side bottlenecks. To this end, the nexus approach has been an emerging field of research, addressing the interconnectedness and synergies between FEW resources while promoting multidimensional resource efficiencies rather than siloed efficiency applications.

Figure 1: FEW Resources interaction chart



'Pune district' in state of Maharashtra, which is host to the urban agglomerate 'Pune city', is the second largest in terms of geographical area and population, and fourth-largest in terms of population density. Over the decades, Pune has established itself to be the educational hub of the country while witnessing simultaneous growth in the industrial (Automobiles, Textiles, Food Processing, Pharmaceuticals, Electronics) and Information Technology sectors. Rapid urbanization and a large influx of migrants has led to an increased burden on FEW resources. Thus, Pune district provides an interesting case study for the FEW nexus approach towards assessing the region's potential in meeting the rising demand challenge while being endowed with limited resources.

Significance: Most of the FEW nexus studies are conducted in the context of climate change impacts focussing on environmental sciences, while studies from the perspective of economic and social sciences remain relatively unexplored. The scale of research has been largely at the national or sub-national level while the emphasis on city or district level has been minimal.

Methodology: Given the role of urbanization, a city or district level study is of greater significance for understanding community-wide FEW consumption patterns and region-specific characteristics of economic activity, thus providing a bottom-up approach to the decision-making process. To this end, the Input-Output (IO) analysis framework has been widely used for quantifying the economic interlinkages and as a basis for carrying forth analysis relating to environmental management. The development of the comprehensive IO framework with emphasis on FEW resources in Pune region is, to the best of our knowledge, the first study of its kind in India and serves as a precursor for effective policy framework, implementation and assessment.

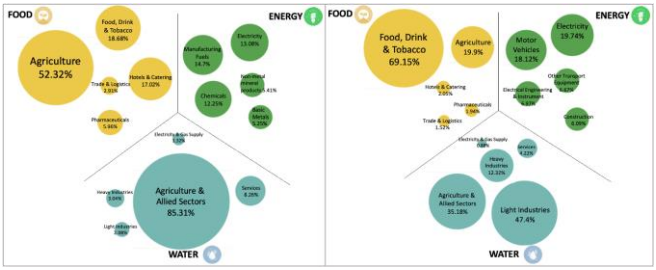
Given this backdrop, the **objectives** of our study are:

- Preparation of Processing Sector of IO transaction table for Pune district.
- Preparation of Household expenditure for Pune district.
- Measuring the FEW impact on Pune district in 2017-18 and 2029-30.
- Evaluating the impact of significant operational policies in Pune district on FEW resources.

Results: For the present study, a 34x34 IO processing sector was constructed. The FEW footprint analysis results show the primary segment has the highest direct food and water footprints, while the secondary segment has the highest direct energy footprint. The key sectors comprising the major share of FEW footprints in the economy are shown in the left panel of Figure 2. On the other hand, the right panel indicates the key sectors driving the total FEW footprints.

The agriculture sector is identified as GHG emission-intensive, accounting for 33% of the total district GHG footprint. The household consumption expenditure pattern is also FEW intensive, with agriculture (34.9%), manufacturing fuels (11.26%) and food processing sector (8.25%) constituting the highest share. Based on the footprint analysis results, priority sectors are identified for efficient utilization of resources.

Figure 2: Direct & Total Resource Footprints-Key Sectors



Furthermore, FEW resources are expected to witness triple-digit growth of more than 135% between 2018-30 through two channels: industrial production and household expenditure. The results show that food, drinks and tobacco, motor vehicles and agriculture sectors will be the largest drivers of FEW resource footprints. This significant increase in sectoral demand is also factored in through a multitude of policies operational at the national, state and district level. Of all the operational policies considered in the study, the Automotive Mission Plan alone has the potential to increase district's electricity-water footprint by around 900% i.e., 1660 Million Units (Mus) and 0.68 Billion Cubic Metres (BCMs) per annum, respectively. Such results reiterate the importance of a resource nexus strategy in the policy planning period itself.

Given the expected increase in resource use through various economic policies, the adoption of measures that promote efficiency in the usage of these resources becomes extremely relevant. Energy efficiency measures such as the adoption of solar energy to meet 15% of Pune's electricity requirement as put forth by the Pune Municipal Corporation (PMC) can lead to a cumulative net GHG savings of 1.9 million tCO_2eq. Simultaneously, the water requirement for thermal power generation, which constitutes about 70% of total freshwater withdrawal by all industries in India, is also expected to decrease by approximately $514m^3$/week per MW. A 10% increase in Liquefied Petroleum Gas (LPG) in the rural region of Pune district where firewood still remains the primary cooking fuel can lead to GHG emission savings of 6.9 thousand tonnes CO_2eq., along with related health benefits. Water-related efficiency measures target the water-intensive cropping pattern in Pune district, where sugarcane, for instance, sources approximately 20,000 litres of water per hectare, given that Pune is one of the six districts constituting 80% share of total state production. Promotion of wastewater treatment and reuse in industrial and commercial sectors can assist in sustaining exponential water demand in the city. Changes in water usage in the household sector is pivotal for Pune district since it accounts for the highest per capita water consumption in India, ranging from 200-270 Litres per Capita per Day (LPCD). The Smart City Mission Plan aims to reduce it to 150 LPCD through proper information dissemination in cooperation with government authorities. This is expected to decrease the total water consumption levels from 0.717 BCM to 0.538 BCM within the region. Finally, efficiency in the food sector can be brought about by actively extending the above discussed efficiency measures of solar energy adoption and reusing treated water to the Food Processing sector and limiting wastage at both industry and household levels.

Conclusion: This comprehensive economy-wide analysis at the district level intends to serve as a precursor to a better understanding of the mixed effects of urbanization and climate change at the regional level. The study not only establishes the interlinkages between the three resources, but also charts the inter-connected resource characteristics in the rest of economy and the activities thereof. Considering this study as a template, future studies can not only replicate this analysis for other urban agglomerations but also go beyond it to factor in inter-district or inter-regional planning for better resource mobilization.