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Analysing Energy Transition by Linking Qualitative Future Energy Scenarios with Quantitative Mathematical Models of Energy Networks: Case Study of the North of Tyne (NoT)

1. Overview

- Combined qualitative and quantitative analysis of energy network models provides a holistic approach to examining the impact of future developments on energy supply and demand.
- In this work, we provide a framework for analysing future energy scenarios by combining qualitative scenarios with quantitative energy models using the Story and Simulation (SAS) approach.
- The framework combines the advantages of both qualitative and quantitative scenarios by taking the qualitative storylines developed by stakeholder workshops and converting them into inputs for quantitative energy models.

2. Qualitative Scenarios

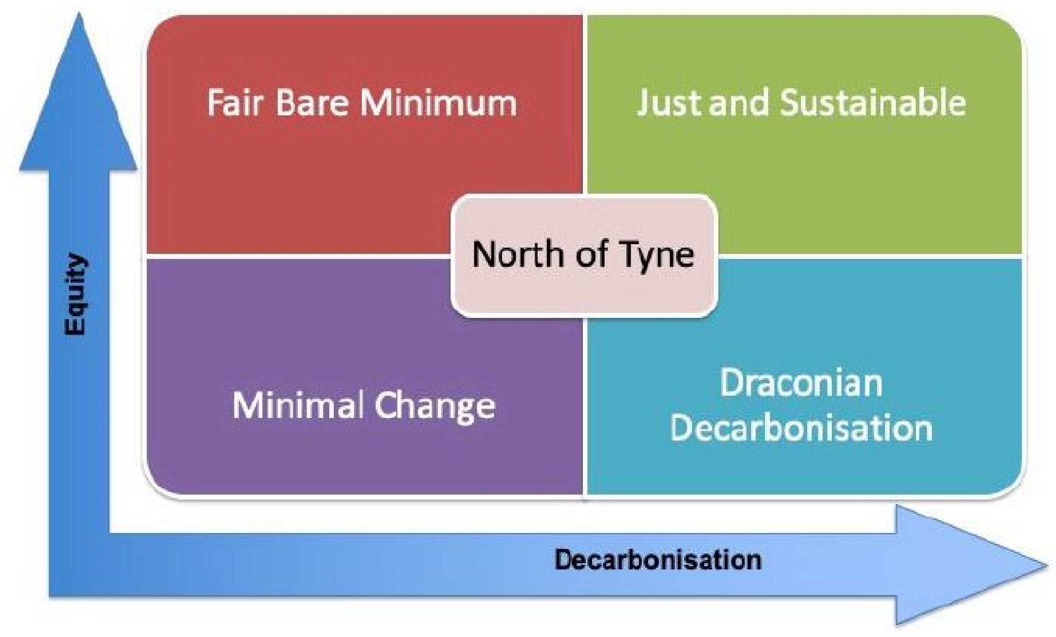

Figure 1: 2×2 Matrix for Energy Futures in the North of Tyne [1]

- The scenarios developed from the stakeholder workshop for the North of Tyne (NoT) region, with equity and decarbonisation as the main drivers:
- Minimal Change (Low Equity, Low Decarbonisation),
- Fare Bare Minimum (High Equity, Low Decarbonisation)
- Just and Sustainable (High Equity, High Decarbonisation)
- Draconian Decarbonisation (Low Equity, High Decarbonisation)

3. Quantitative Model for Integrated Energy Networks

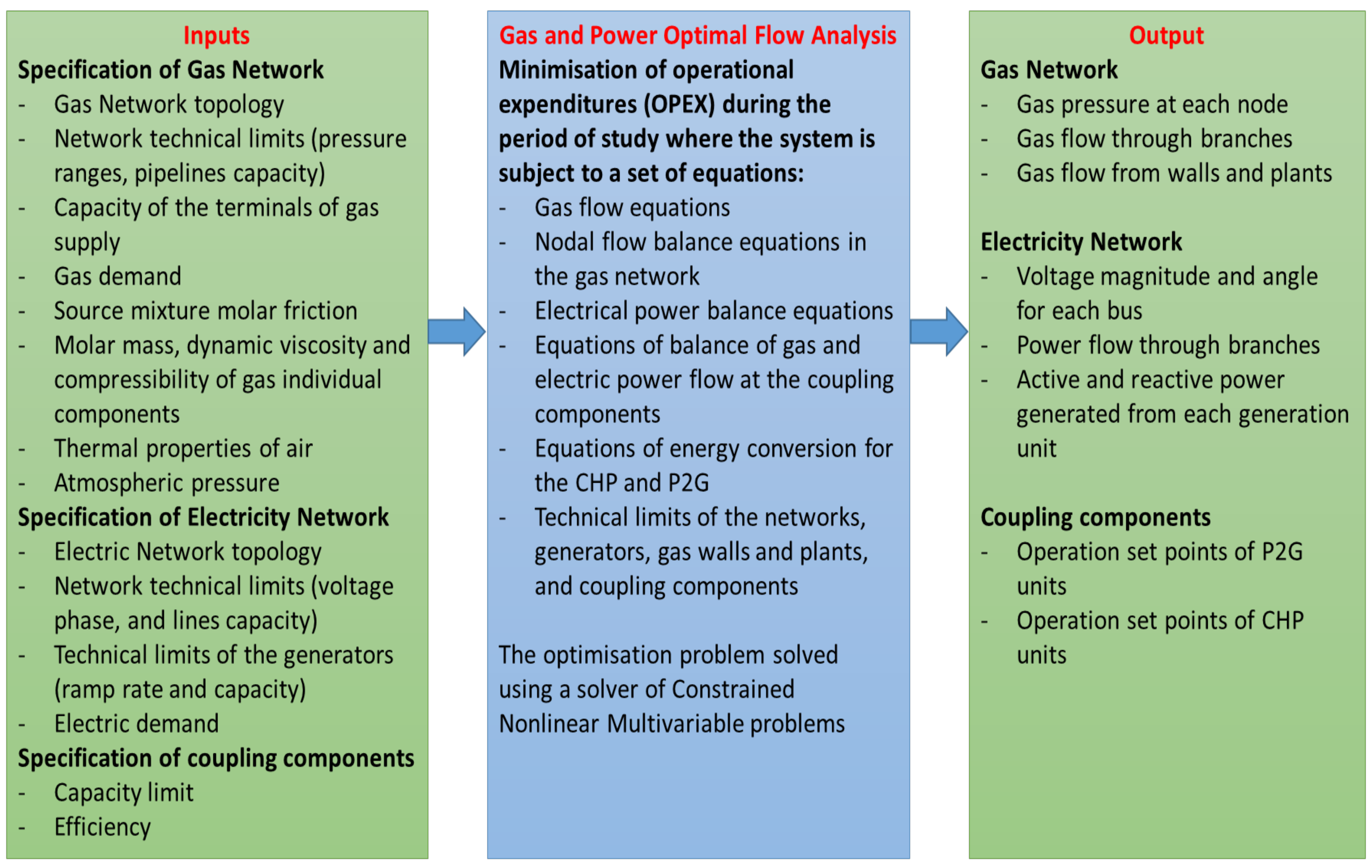

Figure 2: Quantitative model inputs, outputs and algorithms [2]

- Quantitative model consists of a set of nonlinear equations constrained by voltage and pressure balances for electric and gas network nodes.
- The cost minimisation objective function of the integrated energy system is defined as:

Min (Cost of non-gas electric generation + Cost of gas electric generators supplied from another gas network + Cost of gas supply) (1)

Subject to:

$$h(x)=0 \quad (2)$$

$$g(x)\leq 0 \quad (3)$$

where x is the state vector for the angle and amplitude voltages of electrical buses, the pressure of different nodes in the gas networks, h(x) and g(x) are the equality and inequality constraints.

4. Methodological Framework for Soft-Linking Qualitative Scenarios with Qualitative Models

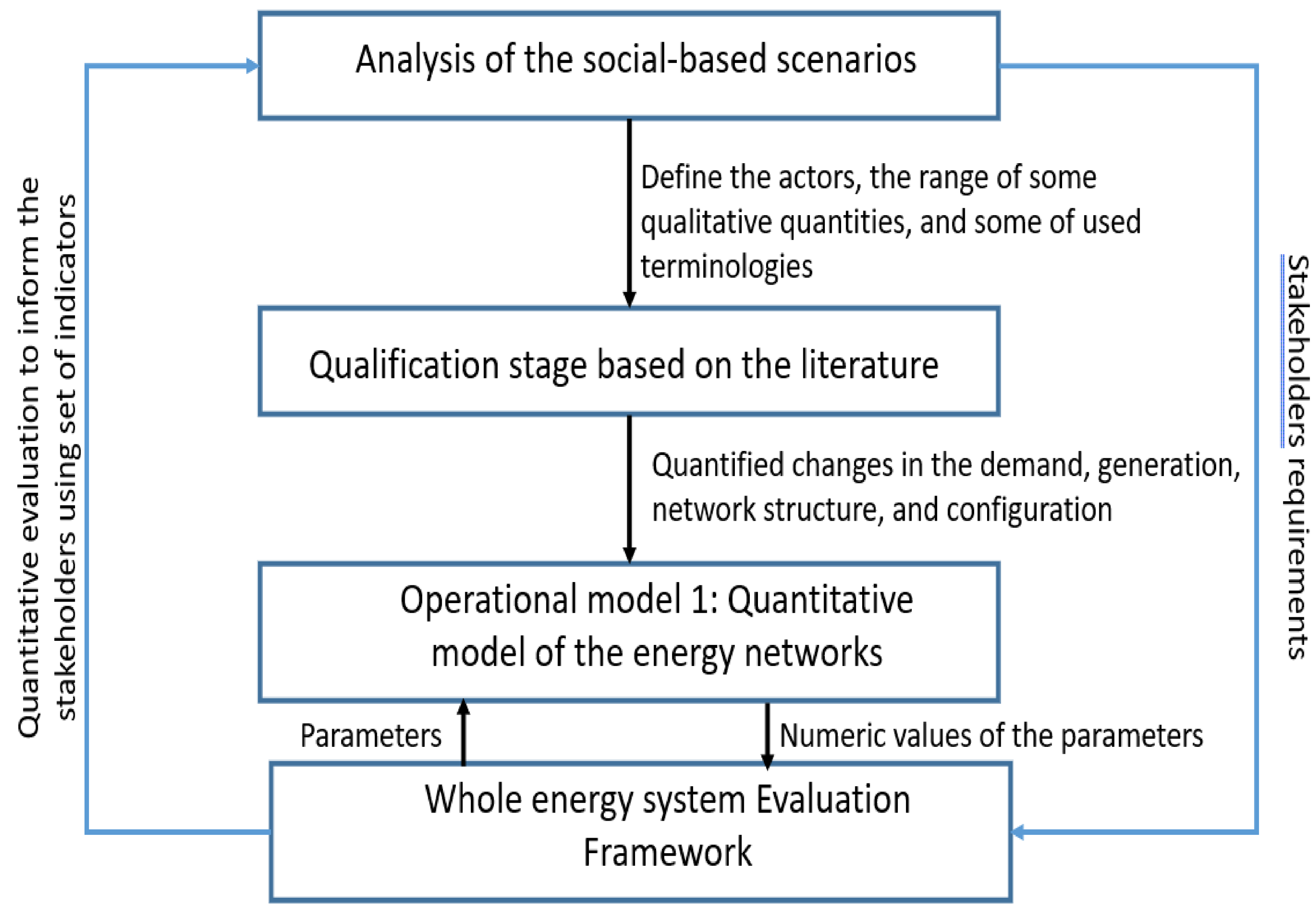

Figure 3: Framework for Soft-Linking Qualitative Scenarios and Quantitative Models

- Key actors in both electricity and gas demand and supply were identified for each qualitative scenario, and surveys prepared to garner the opinions of experts on the actual quantities for the actors in the future.
- Survey answers from experts are converted into quantitative models using Fuzzy-set theory, where actors are expressed in degrees of membership for each survey, which is further consolidated into a single membership function.
- The elicited membership functions for the future energy demand and supply are fed into the quantitative energy model, to evaluate each scenario and therefore provide a realistic prediction of the energy situation in the NoT within the next few decades.

5. Findings and Conclusions

- Linking qualitative scenarios with quantitative energy models is crucial to evaluating whether energy transition objectives are can be met in the future.
- The framework offers a methodological approach to translating qualitative scenarios from stakeholders into quantitative data through an iterative process, serving as input to quantitative energy models.

6. References

[1] Claire Copeland, ''Narrative Future Energy Scenarios for the North of Tyne'', 2019.

[2] [1] Berjawi, A.E.H., Allahham, A., Walker, S.L., Patsios, C. and Hosseini, S.H.R., 2022. Whole Energy Systems Evaluation: A Methodological Framework and Case Study. In Whole Energy Systems (pp.41 82). Springer, Cham

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