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A Strategic Plan for Renewable Energy Transition in a Coal Dependent Region using Participatory Backcasting: The Case of South Kalimantan Province in Indonesia

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ABSTRACT

In this study participatory backcasting was refined to combine the use of existing visions in combination with stakeholder engagement and road-mapping and applied to the regional energy transition in Indonesia's South Kalimantan Province, where the gross regional domestic product strongly depends on coal mining. Based on document analysis, interviews, consultations, and a focus group discussion, we determined necessary changes, driving factors and challenges, and co-created a roadmap towards the preferred Net Zero Emission vision. The roadmap proposes: (1) to increase the capacity of renewable energy, particularly wind and solar, along with battery energy storage systems; (2) to transform economic activities currently based on coal towards bioenergy hubs and to build a regional economy based on renewable energy; (3) to enhance the quality of data on renewable energy potential, power grid flexibility, and variable renewable plants, and (4) to shift culture and behaviour towards energy saving, energy communities, electrification of lifestyles, and the use of renewable energy in industry. Our study contributes to the literature on participatory backcasting by a case on the clean energy transition in fossil fuel-rich nations in the Global South and advances backcasting by using existing visions instead of generating one or several new visions.

Keywords

Participatory backcasting;
Stakeholder engagement;
Transition management;
Net Zero Emissions;
South Kalimantan;
Power plant planning;
Coal Phase Out;
Renewable Energy

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1. Introduction

Energy systems differ significantly between Global North and Global South nations [1]. One key difference is the electricity market. Global North countries generally adopt a liberalized approach to enhance efficiency [2], privatizing power generation, transmission, and distribution [1]. In contrast, Global South countries often maintain a state-owned monopoly in the electricity sector [3]. Additionally, policymaking is typically centralized by the relevant ministry, generally excluding local and regional governments. Nevertheless, policy and research in the Global South are increasingly focusing on the clean energy transition [4].

Differences in energy policy and markets require different planning and analysis tools. Several studies have reviewed tools suitable for Global South countries, mainly focusing on quantitative tools like top-down, bottom-up, and hybrid energy models [5]. These models are powerful for simulating future energy conditions based on different assumptions and transition scenarios [6, 7].

However, they generally assume that scenarios can be implemented with strong policies enabling technological

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List of Abbreviations

BaU	Business as Usual
BESS	Battery Energy Storage System
CC	Current Condition
CCUS	Carbon Capture, Utilization, and Storage
DED	Detailed Engineering Design
DEN	Dewan Energi Nasional (in English: National Energy Council - NEC)
FGD	Focus Group Discussions
GGGI	Global Green Growth Institute
GOI	Government of Indonesia
GRDP	Gross Regional Domestic Product
GT	Green Transition
JETP	Just Energy Transition Partnership
LEAP	Low Emissions Analysis Platform
MEMR	Ministry of Energy and Mineral Resources
NGOs	Non-Governmental Organizations
NZE	Net Zero Emission
PLN	Perusahaan Listrik Negara (in English: State-owned Electricity Company – SoEC)
REBED	Renewable Energy-Based Economic Development
REBID	Renewable Energy-Based Industrial Development
REO	Regional Energy Outlook
RUED	Rencana Umum Energi Daerah (in English: Regional Energy General Plan – REGP)
RUEN	Rencana Umum Energi Nasional (in English: National Energy General Plan – NEGP)
RUPTL	Rencana Umum Penyediaan Tenaga Listrik (in English: Electricity Supply Business Plan – ESBP)
VRE	Variable Renewable Energy
WASP	Wien Automatic System Planning
ZE	Zero Emission

and social changes, which is not always the case [8]. Implementation requires actions from key actors usually not involved in these studies. Therefore, active stakeholder engagement is crucial to deal with varying and possibly conflicting interests on social, environmental, and economic issues, in order to enable effective co-creation of inclusive energy transition policies [9].

Energy model-based studies need to be complemented with stakeholder engagement, such as participatory backcasting, to create a transparent renewable energy vision, foster ownership, and promote collaboration [10]. Unlike forecasting, which produces likely futures based on current trends, and exploratory scenarios depicting possible futures including uncertainties and complexity [11-13], backcasting is used to envision desirable futures and analyse backwards how to achieve them before planning and working towards the endorsed normative future.

Initially developed in Global North countries for renewable energy scenarios [14, 15], backcasting has also been used to address other sustainability challenges at global, national and regional levels, both participatory and non-participatory [16-18]. Moreover, participatory energy planning during project planning and implementation can enhance partnerships, knowledge, awareness, and ownership among communities [19].

Participatory backcasting is increasingly used to analyse clean energy transition visions in countries in the Global South. However, these studies often create new visions and neglect existing ones. Yet using existing visions can make the process more efficient and can build on previous efforts. Our study starts therefore with analysing existing visions in discussions with key stakeholders, reinforcing the most favoured vision through dialogue, and crafting a roadmap. We refined Quist's participatory backcasting approach [20] for renewable energy in a regional context in a Global South country, building on a recent review of energy backcasting and the North-South divide [21]. This refined methodology raises stakeholders' awareness of various existing visions, highlighting the benefits and challenges of each.

Our refined approach was applied to the clean energy transition in South Kalimantan, Indonesia (see Figure 1). Indonesia is one of the seven largest emitters globally, alongside China, the United States, the European Union, Russia, and India. It is a major coal producer and exporter, ranking third in coal production (7.5% of global production) and second in coal exports (345 million tons) in 2021 [22, 23]. Domestic coal consumption reached 133 million tons, primarily for electricity generation (84.3%), followed by the industrial sector (12.9%) and other sectors (2.8%). Coal-fired power plants dominate Indonesia's electricity supply, accounting for 61% of the total 190 TWh of electricity production in 2021 [24].

A key milestone was that in 2022, Indonesia declared a Net Zero Emission (NZE) target for 2060, and energy transition research is quickly increasing [19, 25-27]. The NZE policy will significantly impact the three provinces with the largest coal reserves: East Kalimantan, South

Sumatra, and South Kalimantan [24]. Unlike the other two provinces, South Kalimantan's vision aims at "Energy Independence and Leadership in Renewable Energy Utilization", as stated in the Regional Energy General Plan (RUED) of South Kalimantan [28]. The provincial government aims to increase renewable energy capacity from 48 MW in 2020 to 285 MW in 2025, 490 MW in 2030, and 941 MW in 2050.

Our study addresses the research question: "How can participatory backcasting facilitate the co-production of energy transition in South Kalimantan, involving stakeholders from both local and national levels?" The presence of several contrasting visions for renewable energy development in South Kalimantan suggests that using existing visions, rather than creating new ones, would be more efficient for a participatory backcasting process.

The paper is organized as follows: Section 2 reviews backcasting framework applications for renewable energy transitions in Global South countries. Section 3 presents the developed participatory backcasting methodology. Section 4 reports the results of its application to the energy transition in South Kalimantan, Indonesia. Section 5 evaluates the challenges associated with using this methodology in the province and other countries. Section 6 provides the conclusion. This paper is based on an underlying report [29].

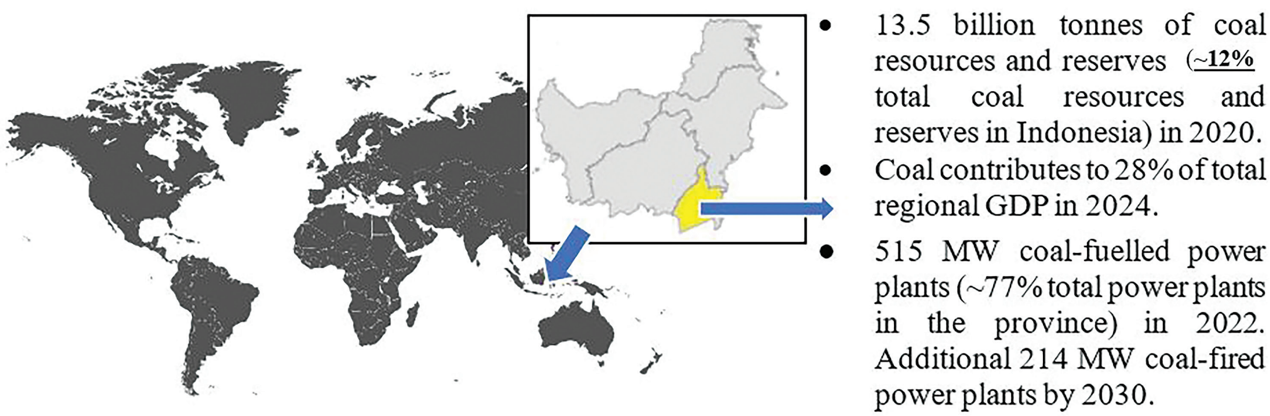
2. Backcasting for Clean Energy in the Global South

The use of backcasting is gradually increasing in Global South countries, as shown in a recent review on renewable energy transitions focusing on the North-South divide [21]. Building on this review, we searched the Scopus database on May 14, 2023, using keywords "backcasting OR back-casting" AND "renewable OR energy OR wind OR solar OR geothermal OR ocean OR wave OR biomass OR biogas OR biofuel".

The search yielded 188 articles, which were manually sorted to extract those relevant to Global South countries, resulting in a sample of 13 relevant articles (see Table 1). Key articles include cross-country analyses by Krewitt et al. [30] and Bataille et al. [31]. Most studies focused on clean energy in individual Asian countries, with one study each from Africa, South America, and Central America. Only three studies used backcasting to analyse a NZE vision, discussing a 100% renewable island in Indonesia [32], decarbonizing transportation in Costa Rica [33], and a Net Zero power system in Malaysia [34].

Six studies in Table 1 employed a backcasting methodology without participatory processes, relying on quantitative tools like Low Emissions Analysis Platform (LEAP) [35, 39], Extended Snapshot [35], Multi Criteria Decision Analysis [36], Bayesian Belief Networks [37], bi-level optimization [38], and Hybrid Optimization of Multiple Energy Resources [32].

Seven studies used various participatory tools, including questionnaires, interviews, consultations, meetings, workshops, and Focus Group Discussions (FGD). For instance, Krewitt et al. [30] developed two emission reduction scenarios across 10 regions and consulted with research institutions, NGOs, and renewable energy industry representatives. Bataille et al. [31] discussed Deep Decarbonization Pathways in a global



Sources: World map from Freepik (premium) and Kalimantan map adjusted from OpenStreetMap

Figure 1: Location and economic characteristics of South Kalimantan.

Table 1: Backcasting studies for clean energy analysis in Global South countries.

Country	Participatory	Number of Vision	NZE Vision
Thailand [35]	No	2	No
Pakistan [36]	No	3	No
Saudi Arabia [37]	No	2	No
China [38]	No	9	No
Philippines [32]	No	1	Yes
Cameroon [39]	No	4	No
10 regions [30]	Yes	2	No
16 countries [31]	Yes	1	No
Chile [40]	Yes	9	No
Costa Rica [33]	Yes	2	Yes
Iran [41]	Yes	3	No
Malaysia [34]	Yes	2	Yes
Qatar [42]	Yes	16	No

collaboration with 16 teams from countries contributing to the reduction 74% of global emissions. Alvial-Palavicino and Opazo-Bunster [40] used a participatory backcasting process for Chile's Energy 2050 vision, including a two-days' workshop.

In addition, Godínez-Zamora et al. [33] held bilateral meetings and two workshops to develop decarbonization scenarios for Costa Rica's transportation and energy sectors. Atabaki and Mohammadi [41] used expert opinions for a Analytic Hierarchy Process and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) in their renewable energy transition study. Chan and Sopian [34] developed Malaysia's Carbon-Free Energy Roadmap (2015–2050) using a participatory backcasting framework, and included task force meetings and a workshop with key stakeholders.

All backcasting studies discussed primarily focus on the shift towards renewable energy. This transition becomes more intricate when a country is a fossil fuel producer. Such a shift involves not only increasing clean energy provision, but also a decreasing economic contribution from the fossil energy sector. Currently, only very few backcasting studies thoroughly explore the vision of transitioning from fossil energy to renewable energy, including phasing out coal and other fossil fuels. For example, Mohammed et al. [42] developed 16 low-carbon scenarios to reduce Qatar's dependence on hydrocarbon revenue through four workshops with policy and technology professionals. Although no specific transition pathway was agreed upon, these workshops provided new insights and facilitated increasing awareness and discussions among key stakeholders.

In Australia, Giurco et al. [43] conducted a backcasting analysis to assess sustainable scenarios for coal utilization in the Latrobe Valley. The study used several participatory methods, including consultations with industrial experts, a workshop on policy priorities with government representatives, followed by participatory review and validation of the developed scenarios.

Our study aspires to make two scientific contributions. First, it enriches the literature on participatory backcasting for transitioning from fossil fuel-based to renewable energy-based economies in a Global South context, through a case study on South Kalimantan, a major coal-producing province in Indonesia. Second, it refines Quist's five-step participatory backcasting framework [20] by utilizing existing visions to enhance the efficiency of the participatory process to facilitate discussions with key stakeholders about contrasting visions and pathways for a regional energy transition.

3. Research Methods

Numerous studies have adapted the backcasting approach to suit their research scope and focus, leading to diversity in domain, methods, participation, and geographical boundaries [17]. Our study starts from the generic participatory backcasting approach by Quist et al. [44] and Quist [11]. Based on our review in Section 2 and our South Kalimantan case study, we refined it as follows.

Our methodology, as shown in Table 2, was refined by adding to identify and compare existing visions and pathways in the second step. Therefore, creating pathways in the fourth step of Quist's participatory backcasting [20] becomes refining and elaborating an energy transition roadmap for the vision most endorsed by the stakeholders involved.

The first step of problem orientation reviews current conditions, regulations, and policies for the electricity system in South Kalimantan, including supply and demand sides, power infrastructures, energy mix, and renewable potentials. It also includes a stakeholder analysis to identify key stakeholders influencing or affected by South Kalimantan's clean energy transition. This was done by analysing official reports and interviewing key stakeholders. All interviews and FGD discussions were

Table 2: The participatory backcasting steps and applied methods.

No	Steps	Content Analysis	Interviews	Consultation	Focused Group Discussion (FGD)
1	Strategic Problem Orientation	√			
2	Vision Comparison	√			
3	Backcasting Analysis	√	√		
4	Roadmap development	√		√	√
5	Impact evaluation	√		√	

recorded, transcribed, analysed, and summarized. Interview results were triangulated using quantitative data and content analysis of reports, regulations, and academic articles.

The second step discusses four visions on regional electricity demands and renewable energy supply, derived from the South Kalimantan Regional Energy General Plan (RUED) [28], State-owned Electricity Company (PLN)'s Electricity Supply Business Plan (RUPTL) [45], IESR research organisation its Regional Energy Outlook (REO) for South Kalimantan [46], and a NZE and Zero Emission (ZE) vision [47]. Different assumptions in these visions lead to varying projected electricity demands and renewable electricity shares. The pathways were compared to assess differences in power generation capacity, electricity production, and emissions.

The third step involves backcasting analysis by discussing the four visions with key stakeholders through interviews. These interviews provided insights on challenges, required changes, strategies, drivers, and challenges. Respondents were selected based on their influence and sector representation. Interview requests were sent to 13 potential respondents, with nine accepting—five from Jakarta and four from South Kalimantan. When relevant, we assign codes (R#)) to quotes from the interviews to clearly indicate who provided inputs. Interviewees included two representatives from energy policy-making bodies (R#11, R#13), an electricity utility company (R#1), the banking sector (R#5), an environmental fund management agency (R#2), the regional government (R#4), a university in South Kalimantan (R#3), a coal and renewable energy industry (R#7), and an international organization on clean energy infrastructure (R#9). One Jakarta stakeholder had a business in South Kalimantan. Interviews were conducted in March and April 2023.

Inputs from stakeholders during interviews were used to craft the roadmap in the fourth step, focusing on "WHAT changes are needed to achieve the vision?", "HOW can the change be achieved?" (strategies and actions), and "WHO are needed for this?" as a WHAT-HOW-WHO analysis [11, 48]. These inputs were enriched through additional literature review, document analysis, and a FGD to enable comprehensive information from various key stakeholders,.

The FGD aimed to raise stakeholder awareness about decarbonizing South Kalimantan's power system and gain commitment for follow-up and implementation. The FGD, attended by 65 participants, including a few attending online, gathered high-level stakeholders from the regional provincial government, PLN, the Regional People's Representative Council, the National Energy Council (DEN), and several universities. The program featured presentations from the regional government, DEN, PLN, and the research team, followed by a discussion session, during which the audience could provide their views and feedback on the proposed draft roadmap.

New information and inputs from stakeholders during the FGD were used to further develop and elaborate the roadmap. The roadmap includes action plans for stakeholders to achieve the envisioned changes, encompassing shifts in economic structure, technology, and culture and behaviour. The study's findings were also discussed with stakeholders to gather their feedback on the drafted roadmap. Consultations took place in July and August 2023 to validate the initial analysis, discuss the proposed roadmap activities and obtain policy recommendations, involving the National Energy Council (DEN), the Provincial Government of South Kalimantan, and PLN.

The fifth step assesses the impact of this study on stakeholders' changes and activities. To ensure continuation and impact, the analysis and actions was used as input to the revised RUED of South Kalimantan, the guide and legal basis for the province's energy planning.

4. Results and Discussion

Results are reported following the five backcasting steps. More details are given in the underlying report [29].

4.1 Strategic Problem Orientation

South Kalimantan has 105 power generation units: PLN owns 101 units, while two are owned by independent power producers and two by excess power producers [45]. Coal-fired power plants have the largest capacity, increasing from 0.12 GW in 2010 to 0.54 GW in 2023 [49, 50]. Several factors contribute to South Kalimantan's current prioritization of coal extraction and investment in coal-fired power plants [51].

First, coal significantly contributes to the Gross Regional Domestic Product (GRDP). The 2010 GRDP reached IDR 157 trillion or US$ 9.89 billion in 2024, mainly from mining and quarrying (24%), agriculture, forestry, and fisheries (13%), and manufacturing industries (12%). The GRDP from mining and quarrying was US$ 2.35 billion in 2022, with nearly 94% from coal and lignite mining [52]. Second, the coal sector receives various incentives like loans, tax exemptions, and a coal price cap policy, making coal-fired electricity cheaper than renewable electricity. Third, the coal industry has strong ties with local government officers and politicians.

As shown in Table 3, South Kalimantan has considerable renewable energy potential, especially from solar, biomass, and wind, according to GOI [53]. The data originates from MEMR, which continually updates renewable energy potential data by installing additional measuring stations and employing enhanced estimation techniques. Recent data shows that solar energy has the largest renewable energy potential in South Kalimantan, 53 GWp [54]. Renewable energy potential is estimated using remote sensing techniques based on satellite data, which is then validated through field measurements.

Conversely, the potential data in RUED [28] is solely based on feasibility studies from only a few locations, resulting in low potentials, although there is the 70 MW wind turbine project in Tanah Laut Regency. So, the renewable energy potential could be higher than reported in official data [58] and needs to be updated. For instance, Langer et al. [55] and Langer et al. [56] utilized wind speed data from the ERA5 database, calibrated with data from the Global Wind Atlas (GWA), while excluding regions unsuitable for wind energy development. Langer et al. [57] used a similar approach, but relied on solar radiation data from the ERA5 database and the Global Solar Atlas (GSA) to estimate solar energy potential in Indonesia.

In Indonesia, energy policies and regulations are based on Article 33 of the 1945 Constitution, governing state authority over natural resources and crucial production sectors. This is further detailed in various laws, including the Energy Law [59], which mandates the formulation of the National Energy Policy by DEN, the National Energy General Plan (RUEN), and Regional Energy Plans (RUED). MEMR develops the RUEN based on the National Energy Policy. According to these regulations, the Electricity Law [60], and the Job Creation Law [61], MEMR also develops the National General Electricity Plan, which PLN uses to create the RUPTL.

Provincial governments must create their RUED aligned with the national plan. Policy development considers other sectoral laws, including those related to

Table 3: Renewable energy potentials in South Kalimantan.

Renewable Energy	Unit	RUEN [53]	RUED [28]	MEMR [54]	Langer et al. [55], Langer et al. [56], Langer et al. [57]
Solar	GWp	6.03	0.017	53.17	258.5 (ground mounted)
Wind	GW	1.01	0.070	8.45	54.6 (offshore) 10.3 (onshore)
Hydro	GW	0.38	0.12	0.12	
Biomass	GW	1.27	0.10		
Industry waste biomass	GW			0.27	
Municipal waste biomass	GW			0.060	
Biogas	GW	0.024	0.025		
Geothermal	GW	0.050	0.050		

emission reduction commitments [62]. Indonesia aims to achieve NZE by 2060 or earlier, as outlined in the Indonesia Long-Term Strategy for Low Carbon and Climate Resilience 2050 [63]. This goal requires substantial funding to phase out coal plants and develop renewable energy. At the 2022 G20 Summit in Bali, Indonesia and other leaders agreed on NZE funding through JETP. Investment mobilization and funding mechanisms are detailed in the Comprehensive Investment Plan (CIP) [64].

4.2 Visions

Table 4 summarizes the four identified clean energy visions for South Kalimantan, showing their renewable objectives, shares, and pathways. One key difference among the visions is the projected electricity demand. The RUED vision [28] projects the highest demand, from 4.7 TWh in 2022 to 10.4 TWh in 2030 and 40.6 TWh in 2060. These projections assume new industrial areas and increased electricity usage per capita from 2.5 MWh in 2025 to 6.8 MWh in 2050. The RUPTL vision [45] projects lower demand but aligns closest with actual data from 2013 to 2022, with per capita demand rising from 0.73 MWh in 2021 to 1.3 MWh by 2030. The demand was extrapolated to 2050 as a Business as Usual (BaU) scenario using the Forecast function in Microsoft Excel. The REO vision [46] uses RUPTL projections for 2021-2030 and RUED projections for 2031-2050. The NZE/ZE vision's projections are similar to the RUED vision [47].

The RUED, RUPTL, and REO visions all assume a minimum 23% renewable energy share of total electricity supply by 2025. On the long-term, the RUED aims for a 31% share by 2050. The NZE/ZE vision targets near-zero emissions in power generation by 2060. Table 4 compares the transition pathways of power plant capacity in the four visions. RUED estimates a power plant capacity of 2.16 GW by 2030, predominantly coal fired. Similarly, RUPTL assumes that coal-fired power plants will dominate, accounting for 69% of the total 1.05 GW capacity by 2030.

For 2030 the REO vision provides two scenarios. The Current Condition (CC) scenario aims for the lowest electricity generation cost without policy interventions, while the Green Transition (GT) scenario includes policies reducing renewable energy project financing costs.

The total capacity in the REO vision is 1.11 GW for CC and 1.86 GW for GT. The disparity arises from the higher capacity for solar farms (0.57 GW) and wind turbines (0.29 GW) in GT compared to no solar farms and 0.08 GW wind turbines in CC. The REO vision has Battery Energy Storage System (BESS) for 1.41 GW in 2050. This BESS capacity was estimated assuming an additional 0.2 MW of BESS capacity for every 1 MW of solar power plant capacity in 2040, and an increase of 0.55 MW for every 1 MW of PLTS capacity in 2050.

The power plant capacity in the ZE vision reaches 2.77 GW in 2030, mainly from solar power plants. The NZE vision is similar to ZE, yet with more solar and less bioenergy. The BESS capacities in the ZE and NZE visions are 1.75 GW and 2.46 GW respectively. The BESS is essential for maintaining a stable and reliable electricity supply in grids with high shares of renewable energy. It stores excess energy during periods of abundant production while discharging during shortage.

Three visions provide the total capacity for 2050. RUED has the lowest power plant capacity at 8.1 GW, dominated by coal-fired plants. Intermittent renewable energy shares include 7% for wind and 1% for solar. The REO-CC least cost vision projects a total capacity of 11.2 GW by 2050, with solar at 22% and wind at 4%.

The third NZE/ZE vision has the highest capacity of intermittent renewable energy generation, with 15.4 GW for ZE and 18.3 GW for NZE. Solar and biomass power plants will dominate in the NZE/ZE visions. Electricity production in the RUED vision will reach 45.2 TWh in 2050, primarily from coal plants. The ZE vision produces around 44 TWh, dominated by biomass and solar power plants. The NZE vision produces 32 TWh in 2050, primarily from solar plants, but with the lowest production due to importing electricity from other provinces.

The sustainability impacts of the four visions are evaluated on electricity production costs and emissions. Table 4 shows that the NZE/ZE vision has the lowest electricity production cost. Regarding emissions, the RUED vision will increase from 5.3 million metric tonnes of carbon dioxide equivalents ($MtCO_{2e}$) in 2022 to 10.0 $MtCO_{2e}$ in 2030 and 40.8 $MtCO_{2e}$ in 2050. The REO-CC vision and NZE/ZE visions will have quite similar emissions between 3.7 to 5.4 $MtCO_{2e}$ from 2022 to 2030. The NZE/ZE visions will have emissions around 1.5 $MtCO_{2e}$ in 2050, continuing to decrease to zero from 2056.

Interviews during the visioning step enabled to prioritise renewable sources for 2050, highlighting floating solar and the need to address intermittency with hydropower, while also raising concerns and different views

Table 4: Overview of the Clean Energy Visions for South Kalimantan.

Description	**RUED**	**RUPTL**	**REO**	**NZE/ZE**
Type	Government planning document	Utility business plan	Report	Book chapter
Source	PGSK [28]	PLN [45]	DEA and EA [46]	Pramudya et al. [47]
Analysis scope	South Kalimantan	All provinces	South Kalimantan	All provinces
Energy model	LEAP	WASP	Balmorel	Balmorel
Analysis period	2020 – 2050	2021 – 2030	2020 - 2050	2022 – 2060
Number of scenarios	One scenario	Optimal Low carbon (LC)	BaU Current Condition (CC) Green Transition (GT)	BaU NZE ZE
Electricity production costs in 2030 (US cents per kWh)	-	Optimal: 9.33 LC: 10.55	CC: 6.57 GT: 6.77	ZE: 5.20 NZE: 5.40
Electricity demand (TWh)				
2025	6.7	4.1	4.1	5.5
2030	10.4	5.6	5.6	6.6
2040	21.9	7.7	21.9	19.9
2050	40.6	10	40.6	32.2
Estimated emission impacts ($MtCO_{2e}$)				
2025	6.8	19.6*	3.9 – 4.5	5.1
2030	10.0	22.7*	3.7 – 5.4	5.2
2040	20.4	-	-	5.6
2050	40.8	-	-	1.5
Power plant and BESS capacity (MW) by 2030 [and 2050]				
Coal	1,304 [6,804]	729	680 - 699 [906]	ZE: 781 [128], NZE: 781 [1,354]
Gas	320 [320]	121	160 - 166 [5,741]	ZE: 457 [17], NZE: 457 [17]
Oil	50 [50]	101	37 - 40 [201]	-
Hydro	121 [121]	30	115 - 121 [20]	ZE: 29 [117], NZE: 29 [117]
Wind	300 [600]	70	80 - 290 [504]	ZE: 70 [1,006]. NZE: 70 [1,006]
Solar	29 [120]	4	0 - 570 [2,417]	ZE: 1,348 [8,858], NZE: 1,395 [13,155]
Bioenergy	20 [20]	-	4 - 9 [-]	ZE: 60 [3,455], NZE: 60 [118]
Geothermal	[40]	-	[50]	[50]
Waste	20 [40]	-	-	-
BESS	-	-	- [1,410]	ZE:10 [1,750], NZE:19 [2,459]
Electricity production (GWh) by 2030^{+} [and 2050]				
Coal	8,745 [39,769]	13,978	16,063	ZE:4,882 [843], NZE:4,790 [9,636]
Gas	460 [625]	4,093	6,317	ZE:1,073 [10], NZE:1,017 [10]
Oil	174 [172]	135	-	-
Hydro	530 [530]	5,838	3,333	ZE:108 [446], NZE:108 [446]
Wind	1,464 [2,628]	196	254	ZE:230 [3,302], NZE:230 [3,282]

Contd...

Contd...

Solar	128 [350]	288	317	ZE:1,830 [11,995], NZE:1,893 [17,764]
Bioenergy	163 [178]	1,910	254	ZE:682 [27,278], NZE:662 [955]
Geothermal	[315]	-	-	ZE: [394], NZE: [376]
Waste	140 [280]	-	-	-
Hydrogen	[315]	-	-	-
BESS	-	-	-	ZE: -10 [-223], NZE: -20 [-427]

Note: *Total emissions from electricity generation in five provinces in Kalimantan Island. Abbreviation: RUED - Regional Energy General Plan; RUPTL - Electricity Supply Business Plan; REO - Regional Energy Outlook; NZE - Net Zero Emission; ZE - Zero Emission; LEAP - Low Emissions Analysis Platform; WASP - Wien Automatic System Planning. + Electricity productions in RUPTL and REO are for the whole Kalimantan region.

on strategies, plans, and instruments. The four visions were also discussed during a FGD in September 2023, in Banjarbaru, South Kalimantan. The FGD with 64 participants gathered key regional and national stakeholders to discuss visions, pathway activities and policy recommendations.

The information and feedback gathered during the FGD were synthesized to further develop the roadmap. This resulted in four main themes for transformational change: economic structure, technology, culture/ behaviour, and policies/institutions. The FGD participants did not directly agree to select one of the four presented visions. However, all participants supported a higher use of renewable energy compared to the RUED and RUPTL visions, and preferred the NZE vision over the ZE vision. The NZE vision is characterised by a strongly increased use of new renewable energy and will reduce not only the use of coal-fired power plants, but also requires the implementation of CCUS on remaining operational coal-fired power plants.

4.3 Backcasting Analysis

Various transformational changes are needed for the NZE energy transition in South Kalimantan [51]. Renewable energy development should be systematically pursued through changes in four key areas: economic structure, technology, culture and behaviour, and policies and institutions. Table 5 outlines the necessary changes and related challenges.

As a key driving factor, the central government has issued regulations in the energy, environment, and financial sectors supporting the transition to renewable energy. Moreover, all provincial governments in Kalimantan are committed to developing and utilizing their energy sources to support industrialization. Environmental regulations and the NZE policy are also strong institutional drivers for renewable energy development. Banks support the energy transition to mitigate risks through green financing, community awareness events, and promoting environmental preservation, according to R#5. In addition, industries are adopting Environmental, Social, and Governance standards and practices. For more details, see the underlying report [29].

4.4 Roadmap

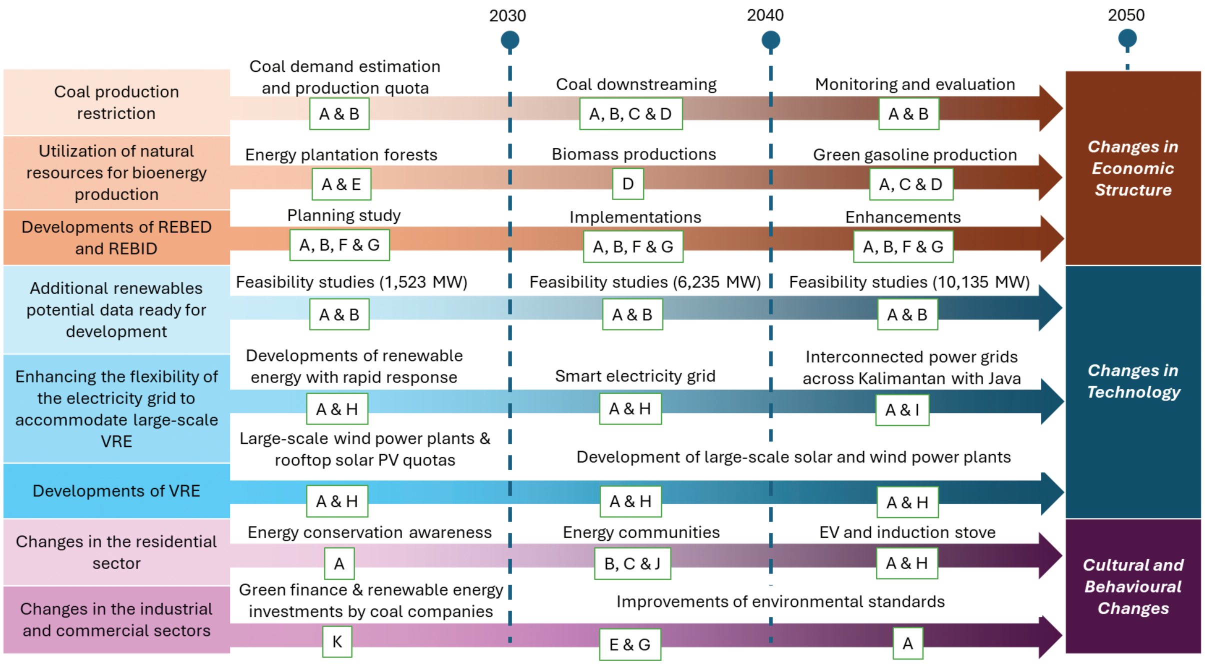
The fourth step involves creating the Energy Transition Roadmap as shown in Figure 2. It shows the changes and activities for changing (1) economic structure, (2) technology and infrastructure, (3) cultural and behavioural change, and (4) policy and institutions. The economic structure category of the roadmap in Figure 2 includes restricting coal production, utilizing natural resources for bioenergy, and developing Renewable Energy-Based Economic Development (REBED) and Renewable Energy-Based Industrial Development (REBID) (R#11).

In the short term, the South Kalimantan Provincial Government and MEMR need to estimate coal demand, propose coal production quotas, and ensure coal-fired plants equipped with CCUS technology. Additionally, the Provincial Government should encourage palm oil businesses to produce green fuels from existing plantations, mills, refineries, and biodiesel industries (R#4). Bioenergy should be sustainably produced by cultivating bioenergy plants on degraded lands through social forestry programs [65]. This will promote bio-based economic growth and reduce gasoline imports.

Important in the Energy Transition Roadmap in Figure 2 is the development and upscaling of solar and

Table 5: Required Changes and Challenges.

Areas	Required changes	Challenges
Economic structure	• Controlling and phasing out coal production. • Developing other economic sectors.	• Limited funding
Technology & infrastructure	• Modernizing control systems • Developing renewable energy power plants with rapid response like hydro. • Expanding wind and solar power plants, bioenergy development. • Interconnecting power grids across Kalimantan and possibly with Java.	• Significant investment costs. • The intermittent nature of wind and solar energy.
Culture and behaviour	• Encouraging green investments by banking sector. • Adopting energy conservation, electric stoves, and electric vehicles by societies.	• Public resistance. • Lack of participation opportunities.
Policies, Institutions, Finance	• Harmonizing policies, regulations, and activities. • Using market-based instruments and non-state budget funds for renewable energy development. • Policies facilitating and enabling changes in economic structure, technology, infrastructure, financing, culture, and behaviour	• Conflicting policies.



Stakeholders: M1 – MEMR, M2 – Ministry of Environment and Forestry, M3 – Coordinating Ministry of Economic Affair, M4 – Ministry of Industry, G – Provincial Government of South Kalimantan, I – Industry, P – PLN, B – Banks, R - research institutions/ universities, N – NGO

Figure 2: Renewable Energy Transition Roadmap for the province of South Kalimantan.

wind power plants. This involves mapping renewable potential and conducting feasibility studies (R#11). Increasing Variable Renewable Energy (VRE) production needs increased power system flexibility. This requires that PLN will enhance grid flexibility for large-scale VRE expansion through controllable generation, energy storage, demand response systems, network expansion, and flexible alternating current transmission assets (R#9; R#13). The South Kalimantan Provincial Government, community, PLN, and MEMR need to collaborate to develop dispatchable renewable generators, like wind plants with storage, biomass, refuse-derived fuels, and hydropower plants (R#1;R#2;R#11). These stakeholders and private sectors should also collaborate on the electrification of lifestyles and mobility.

Changing culture and behaviour is needed in the residential sector through increased adoption of energy efficient appliances, induction stoves and electric vehicles, while in industrial sectors it is needed to enhance investing on renewable energy and implementing Green Industry Standards set by the Ministry of Industry across all industries in South Kalimantan. This builds on existing programs to enhance energy efficiency awareness in the public and manufacturing sectors, such as energy-saving label regulations and minimum energy performance standards for LED lamps by MEMR [66].

In the medium term, establishing energy communities will be needed, especially in areas with limited supply. Local universities, with support from the South Kalimantan Provincial Government and stakeholders, should develop a community-oriented public-private partnership (PPP) business model (R#3). This new model builds on the traditional PPP framework by actively involving local communities in every stage of a project—from planning and decision-making to implementation [67]. Community refers here to local groups that have a direct connection to the project's area or issue. Such local actors do not typically have the technical or financial expertise of independent power producers. The goal of the community-oriented PPP model is not to replace independent power producers but to bring local interests and support into the energy project ecosystem. Examples include off-grid renewable energy systems for lighting, cooking, communication, and electric motorbikes in South Kalimantan villages [67].

4.5 Impact Evaluation

To what extent have stakeholders in South Kalimantan already undertaken activities in line with the NZE vision and roadmap during and after this study. A major result was that the South Kalimantan government in collaboration with the Global Green Growth Institute (GGGI) reviewed the RUED in 2024 in order to increase renewable energy utilization [68], which is awaiting formal approval in 2025. In addition, the Provincial Government and the Bank of Indonesia held several seminars on sustainable and green initiatives to enhance awareness and encourage collective action for green economic development, particularly in South Kalimantan. This participatory backcasting study for the clean energy transition in South Kalimantan also supported the provincial government's efforts to reduce emissions and feeds into the development of the new South Kalimantan RUED.

In addition, the FGD in September 2023 also increased the collaboration between participating stakeholders. For instance, the FGD in South Kalimantan contributed to tangible cooperation between PLN and the Tanah Bumbu Regency Government on the feasibility study and Detailed Engineering Design (DED) of the Kusan Dam. The dam could be used for a 26.7 MW hydropower plant consisting of three turbines with individual capacities of 8.9 MW and a planned discharge of 12.7 m^3/second, but the dam had not yet been included in PLN's RUPTL despite earlier requests. As a result, a new request will be included in the next RUPTL.

5. Discussion

Due to the current high capacity of coal-fired power plants, the South Kalimantan power system is vulnerable to increasing coal prices, especially if the Domestic Market Obligation policy setting the maximum price of high-grade coal at US$ 70 per ton will be revoked [46]. Therefore, the South Kalimantan Provincial Government aims to transition from a coal-based economy to renewable energy, facilitating local industries and communities rather than prioritizing coal export. During the transition, the government could temporarily undertake coal down-streaming by processing coal into higher-value products with lower environmental impacts.

Coal can be converted into syngas for co-firing fuel to reduce emissions in power plants [69]. The syngas can be further processed into ammonia for fertilizers and methanol [70]. Additionally, coal can be processed into activated carbon for filtering water and air [71]. Coal down-streaming can also provide materials for electric vehicles and renewable energy power plants. Research efforts can focus on extracting coal-based sources into rare earth elements and critical minerals needed for the clean energy transition [72].

South Kalimantan is also fostering a bio-based economy to produce green fuels, but palm oil production has significant CO_2-eq emissions, due to field operations, oil mill processes, and refinery energy use. The Indonesian government promotes emission reductions in palm oil through certification initiatives like the Roundtable on Sustainable Palm Oil and Indonesia Sustainable Palm

Oil, which could reduce emissions by 35% compared to uncertified palm oil [73]. Palm oil certification can also lower poverty rates in palm oil producing villages [74]. Palm oil has higher oil yields per area than other crops, highlighting the need for research comparing the environmental, social, and economic impacts of different vegetable oils.

Another issue to discuss is the calculation of BESS capacity for smoothing. DEA and EA [46] used a simplistic ratio solely based on solar energy capacity. A similar method is adopted in the newly launched RUPTL 2025–2034, (see page V-184), which, when translated, states that "BESS capacity for smoothing is approximately 10–20% of the installed PV capacity"[75]. However, this simplification can be criticised and a more accurate BESS capacity calculation should incorporate multiple influencing factors, such as meteorological conditions, PV module characteristics, battery degradation rates, and system replacement thresholds [76]. Without such considerations, the capacity estimation remains vulnerable to inaccuracies, possibly affecting grid stability and investment returns. Therefore, future energy modelling studies could include more comprehensive calculation methodologies of its technological options. However, despite that this is highly relevant for more detailed and site-specific studies, but might only limitedly affect the overall outcomes of this study.

Our study offers two benefits for enhancing energy planning practices. The first benefit is engaging stakeholders at both national and local levels. This includes government, electricity companies, mining companies, banking, NGOs, and academia, unlike the MEMR, DEN, and PLN energy planning processes, which typically involve only their internal units and relevant central government ministries/agencies. Participatory backcasting studies employ similar participatory techniques, but previous studies generally create new visions, which requires more time and efforts, including to engage and convince stakeholders. In addition, our study is employing existing visions rather than creating new ones, while further refining and evaluating the most endorsed vision by developing a roadmap using stakeholder inputs. Finally, the refined participatory backcasting methodology can be replicated in other provinces of Indonesia and in regions and islands in other countries.

The FGD participatory process allowed local stakeholders in South Kalimantan to convey their views and concerns to central government policymakers. The discussion focused on granting more authority to local governments, incorporating renewable energy project proposals into PLN's RUPTL, and providing guidance for transitioning from coal-based economies to achieve the NZE target, while also utilizing stakeholders' their expertise. For instance, a PLN representative proposed to develop waste-to-energy and biogas plants from palm oil mills, highlighting their potential to reduce reliance on coal power plants. It was also raised that a lack of integration, load following, and storage cost considerations in the visions may lead to discrepancies in power plant technology selection and costs.

The one-day FGD was insufficient to thoroughly discuss all complexities of South Kalimantan's energy system towards renewables and NZE. Time constraints prevented detailed examination of the energy models underlying the clean energy transition visions, which could also be too technical for some of the attendees. The relatively short duration did also not allow for detailing a roadmap, which was completed after the FGD using discussions, interviews, and stakeholder consultations.

Despite these challenges, all participants agreed on the need for South Kalimantan to support the NZE policy and to increase renewable energy use. Notably, the preparatory engagement with stakeholders was very important to prepare for the workshop and achieve results and commitment, but a longer participatory process with several FGDs would certainly add value, It is worth mentioning that through the use of existing visions more results could be achieved in a single day workshop.

6. Conclusion

This study was conducted to support the clean energy transition in South Kalimantan using the following research question: "How can participatory backcasting facilitate the co-production of energy transition in South Kalimantan, involving stakeholders from both local and central levels?". The answer to this question is important because energy planning in Indonesia is generally carried out by the national stakeholders MEMR, DEN, and PLN.

Typically, energy planning does not involve regional governments, which have a better understanding of the energy needs in their respective regions. Regional governments also engage in regional energy planning, documented in the RUED. However, policymakers at the national level do not incorporate the regional RUED into their national planning processes. As a consequence, energy planning at the central level and RUED have limited synchronization.

Our study refined a five step participatory backcasting approach by Quist [20] to study the clean energy transition in South Kalimantan. The first strategic problem orientation step used a content analysis to review the condition of the power system in South Kalimantan, renewable energy potentials, and stakeholder analysis. The second visioning step compared four existing energy transition visions in South Kalimantan instead of generating new visions.

The third backcasting analysis step used content analysis, interviews, and draft report consultations to identify challenges, drivers, necessary changes, and strategies for implementing changes. The fourth roadmap development step was based on stakeholders' inputs during interviews and the FGD, which were categorized into four change themes: economic structure, technology and infrastructure, cultural and behavioural, and policy and institutional transformations. The fifth impact evaluation step discusses the activities and changes undertaken by stakeholders during and after the completion of this study.

In conclusion, this study presents a refined participatory backcasting study that involves stakeholders from both national and regional levels. The design of the study is interdisciplinary addressing technology, economic/financial, environmental, and socio-cultural aspects bringing together also multiple levels of policy and governance.

However, our study has several limitations regarding to what can be achieved with participatory techniques when engaging stakeholders in the creation of roadmaps. As stakeholders have diverse interests, some of which may conflict, raising views and preferences is very well possible, but reaching consensus and full agreement usually requires more time.

As a result, the participatory techniques for drafting roadmaps were confined to interviews, consultations, and the FGD. Due to time constraints, this study was unable to conduct more workshops, FGDs or other participatory activities. Consequently, the study could not secure a collective commitment from all stakeholders to implement the roadmap, though the FGD and our study contributed to several impacts, acknowledging that stakeholder meetings are important steps to raise commitment and awareness towards more widely supported agreements.

Another limitation is that we only used articles using the term backcasting in title, keywords, or abstract, while there might be relevant publications using terms like scenarios, or socio-technical transition for the further development of a toolkit for participatory energy backcasting for regions. For instance, Zhang and Lucia [77] use transition research tools and different types of anchoring, while Waenn et al. [78] use scenario analysis to investigate 100% renewable energy supply at the regional level, though in an European context.

Looking ahead, future backcasting studies could strive to develop more elaborate participatory techniques, such as organizing workshops that involve more representatives from each stakeholder. This can be needed as high-level participants may have time constraints, limiting their availability and active participation in series of workshops. Subsequent studies are recommended to invite also representatives from policymakers at less senior levels in follow-up meetings and workshops. While these representatives may not have decision-making authority, they possess sufficient knowledge for analysing issues and required solutions supporting the commitments and direction set or to be set by high-ranking decision makers in the early phase of a backcasting study.

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