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Aligning Engineering Curricula with Energy Industry Demands—The 3P Model of Policy, Pedagogy, and Practice

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Aligning Curricula with Energy Industry Demands - The 3P Model of Policy, Pedagogy, and Practice

Abstract

This study introduces a "3P" model—Policy, Pedagogy, and Practice—to address the need to tackle the difficulties of current engineering curricula to adapt to the rapidly evolving demands of the industry. A mixed-method approach is employed, which combines quantitative surveys and qualitative interviews with industry professionals, policymakers, and educators. This methodology provides a holistic view of the interactions between national energy policies, industry needs, and educational strategies. Key findings highlight a significant gap in current engineering curricula, primarily due to ineffective pedagogical strategies and delayed curriculum updates. The proposed "3P" model, with the key enablers and barriers identified, can serve as a framework to integrate policy-informed competencies, innovative pedagogy, and industry-relevant skills into engineering education, which points out the necessity for rapid adaptation in educational institutions to match industry advancements. The study also explores the model's transferability across various engineering disciplines to demonstrate its broad applicability. Recommendations focus on enhancing industry-academia collaboration, clear policy interpretation, continuous professional development for engineering academics, and strategic curriculum updates.

Keywords—energy policy, industry demand, curriculum development, renewable energy.

1. Introduction

The evolving landscape of the energy sector presents new challenges and opportunities in engineering education, considering a significant shift towards renewable energy sources [1]. This policy-driven shift necessitates a workforce adept in renewable energy integration. Consequently, a re-evaluation and subsequent update of engineering curricula and workforce development programs are imperative to align with these emerging demands [2]. However, a notable misalignment can be identified between current engineering curricula and the practical needs of the energy sector [3]. This discrepancy mainly arises from the lag in updating educational content to reflect rapidly evolving industry requirements [4]. Educators often find themselves grappling with unclear guidelines on the factors influencing course redesign, leading to a slow renewal process, ineffective teaching strategies, and outdated course content [5]. If this is not addressed, the gap could negatively impact the readiness and competence of engineering graduates, potentially affecting the job markets of various engineering sectors. To this end, an instructional framework needs to be developed to produce competent professionals and drive innovative and sustainable education in the rapidly transforming engineering disciplines.

This study introduces a "3P" model—Policy, Pedagogy, and Practice—as a framework to explore the dynamic interplay among the key stakeholders in engineering education, as shown in Figure 1. The model underscores the interaction among the national energy policy, industry demands, and educational strategies, encompassing pedagogy and practice. While the "3P" model does not prescribe specific teaching methods, it highlights critical factors for consideration in curriculum development, which provides a holistic approach to strengthening the connection to the authentic industry. Therefore, this model aims to facilitate a more rapid and industry-relevant curriculum development process. Incorporating policy-level insights ensures that the updated curriculum is aligned with current industry demands and has the flexibility to adapt to future changes. The aims of this study are:

- Investigate the perceptions of the critical stakeholders in the "3P" model on curriculum development,
- Develop a detailed model mapping the complexity and dynamism of the Policy – Pedagogy – Practice model by identifying the enablers and barriers that characterize the interactions between each pair of components within the model, and
- Demonstrate the transferability of the "3P" model to underscore its potential in fostering industry-responsive educational initiatives.

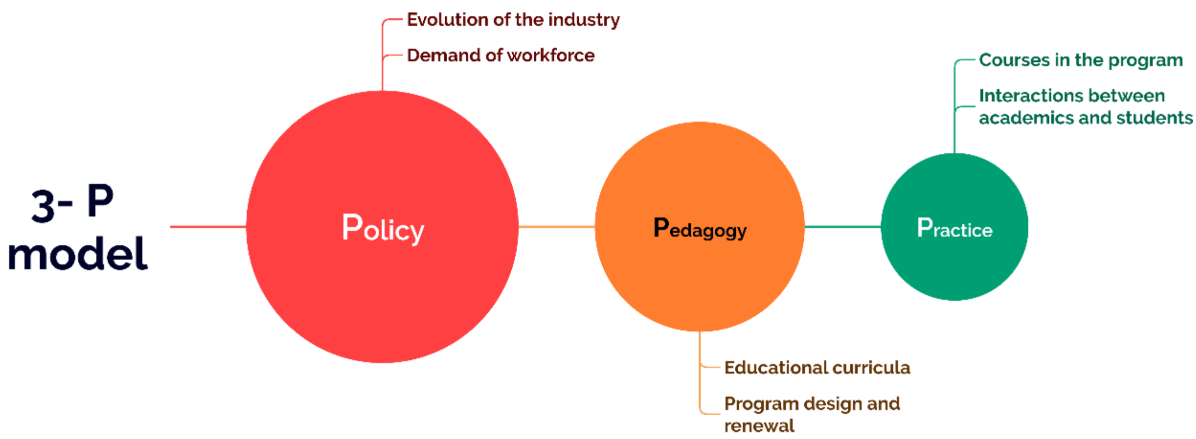

Figure 1 "3P" model (Policy – Pedagogy – Practice).

The research employs a mixed-methods approach, combining quantitative and qualitative data from industry professionals, policymakers, and educators. The comprehensive data collection enables a multi-dimensional exploration into effective curriculum development, particularly in the context of renewable energy. The paper is structured as follows: Section 2 delves into existing studies on curriculum development within energy systems. Section 3 details the methods and instruments for collecting and processing quantitative and qualitative data. Section 4 presents the findings, projecting the insights from the stakeholders' responses. This section includes descriptive statistics from surveys and thematic interpretations from interviews. Section 5 explores the transferability of the "3P" model and demonstrates its applicability beyond the specific context of this study to other engineering disciplines. Recommendations and future work are discussed in the conclusion section.

2. Literature Review

The scope of engineering education in energy systems has been evolving in response to global shifts towards sustainable energy sources. This evolution is characterized by a complex interplay of curriculum development, industry demands, and policy influences [6].

A pivotal study utilizes the renewable energy engineering degree at Murdoch University as a case study to show the necessity of restructuring their curricula in alignment with the industry's evolving demands [7]. This alignment is crucial for equipping students with in-demand competencies and maintaining relevance between program outcomes and industry expectations. Complementing this perspective, another research highlights the growth of the renewable energy industry and the consequent surge in demand for proficient professionals [8]. It proposes a more integrated educational approach to incorporating technology, economics, and policy to bridge the gap that traditional engineering courses might leave in the context of renewable energy utilization. Further expanding on these challenges, another study delves into the approach to embedding renewable energy concepts within engineering curricula, which uncovers the interdisciplinary nature of the subject [9]. This approach involves developing and adapting new courses to meet industry demands.

The literature also reveals a collection of strategies employed in curriculum development within energy systems. For instance, Carroll's work emphasizes the integration of energy systems with environmental and economic considerations with a modular case-study strategy for effective knowledge transfer [10]. Moreover, Mohan et al. propose a curriculum that centered around electric energy systems, focusing on foundational courses for undergraduate students to provide career flexibility [11]. This curriculum was developed with insights from experts in the field and further disseminated through the Consortium of Universities for Sustainable Power, garnering participation from 170 universities. However, it primarily addresses the undergraduate program, and the postgraduate level is less explored. Reed and Stanchina propose a renewed curriculum in power engineering that incorporates smart grid technologies and clean energy integration [12]. They suggest a model that includes distance learning options to widen student and stakeholder engagement. However, this work lacks empirical evidence to validate the effectiveness of the proposed educational models, particularly the effectiveness of distance learning in conveying complex engineering concepts. Tate et al. focus on the development of interactive curriculum materials via collaboration between the power systems industry and education researchers to ensure skill relevance [13]. These materials are designed to be technically sound and align with national accreditation standards and current industry policies. Yet, the scope and impact of their dissemination efforts across educational levels remain unclear. [14] developed a new course in renewable energy systems for electrical engineering students in Jordan, which combined practical laboratory work with theoretical knowledge in the course. The course uses small-scale design projects, such as off-grid photovoltaic systems, to improve the students' hands-on skills. The study only covers a small sample size, which may not fully capture the course's effectiveness.

Despite these innovative strategies mentioned above, a notable gap persists in pedagogical approaches, particularly in integrating practical, industry-relevant skills and knowledge. In response to this gap, some programs have immensely embedded cutting-edge technologies and concepts relevant to renewable energy [6, 15], while others appear to lag, which indicates the need for continuous curriculum development and updates.

A study in 2006 highlighted the importance of incorporating renewable energy topics in engineering and technology courses at a program level. The changes emphasize the environmental and national policy concerns [16]. This study sheds light on traditional energy source coverage in the existing program and explores how to better prepare graduates for the transition to energy generation. Furthermore, a multidisciplinary postgraduate program at Murdoch University demonstrates the integration of energy technology, policy, economics, and environmental and social issues. One of the innovative contributions is offering both on-campus and online access to cater to diverse student needs [17]. However, a comparative analysis with other renewable energy programs is lacking, which could offer more insights into its benefits or limitations.

Finally, it is worth noting that national energy policies significantly influence the renewable energy sector's needs and expectations [18-20]. Literature indicates a direct correlation between policy initiatives and industry dynamics, where shifts in energy policy can lead to substantial changes in industry practices and workforce requirements [21, 22]. These studies explore the impact of energy policies on educational curricula and how these, in turn, meet industry requirements.

In summary, the literature presents a continuing trend toward integrating renewable energy topics into engineering curricula worldwide. Future directions suggest a focus on interdisciplinary approaches and the development of technical expertise, with various enablers and barriers identified in aligning engineering education with industry needs. The "3P" model proposed in this paper can be regarded as a framework projecting this interplay. It targets curricula responsive to policy changes and industry demands and guides educators when redesigning courses or programs.

3. Data Collection and Processing

The data collection incorporates quantitative and qualitative methods to understand the research scope comprehensively. The quantitative data (i.e., survey responses) are exported from Qualtrics and analyzed using MS Excel to discern the descriptive statistics of stakeholders' perspectives. For qualitative data, interviews are transcribed and undergo data cleaning to remove irrelevant content. These transcripts are then imported into NVivo for coding and identifying common themes. This approach ensures a thorough and accurate interpretation of both quantitative and qualitative data.

3.1. Industry stakeholders

To gain insight into the recent evolution of the industry and the workforce demands in the energy sector, an online survey was conducted targeting senior professionals in the electrical power industry. The first part of the survey collected background information about the participants, including their industry affiliation, associated organizations, and areas of expertise. The main body of the survey delved into:

- Frequency of interaction with students/graduate engineers.
- Rating of knowledge and technical skill level of junior engineers in energy systems upon graduation.
- Alignment of current engineering education with the industry's needs.
- Preparation of educational institutions for the evolving energy policy landscape.
- Change in recruitment requirements for graduate positions in terms of technical knowledge and skills.
- Impact of national energy policy on expectations for new hires.
- Impact of energy policies on energy-related positions in the company.
- Avenues to provide feedback to higher education institutions regarding graduate engineers' requirements.
- Frequency of collaboration with educational institutions to ensure curriculum relevance.

Participants were also asked if they would participate in a 30-minute follow-up interview. The interview provides more qualitative information to better understand the participants' survey responses and deepen the study's spectrum. The questions asked in the interview include:

- Preparedness of recent graduates for the energy sector.
- Strategies to better align industry needs with engineering education.
- Collaborative experiences with educational institutions for curriculum relevance.
- The role of national energy policy in shaping new hire expectations.
- Identifying skill and knowledge gaps in recent energy sector entrants.
- Impact of changes in national energy policy on expectations for new hires.

3.2. Engineering educators

Engineering educators in energy systems are recruited for surveys and interviews to investigate the "Pedagogy" and "Practice" aspects of the model. The first part of the survey examines the participants' teaching experience in energy systems at the university level and the extent of engagement with the electric power industry and relevant government departments. The main body of the survey delved into:

- Alignment of power engineering curriculum with industry needs in terms of renewable energy integration.
- Comprehensiveness of the power engineering curriculum in providing necessary knowledge and skills.
- Rating the students' knowledge and technical skill level in energy systems upon graduation.
- Importance of teaching industry-specific knowledge and skills (e.g., PSCAD) in power engineering.
- Importance of teaching fundamental knowledge and skills for future use of industry-specific tools.
- Likelihood of integrating new topics (e.g., grid connection knowledge) into course materials.
- Frequency of course content updates.
- Frequency of consultations with industry professionals for curriculum relevance.
- Influence of national energy policy on curriculum development.
- Understanding of national energy policy, its goals, and its impact on the electric power industry in Australia.

Participants were also asked if they would participate in a 30-minute follow-up interview. The interview provides more qualitative information to better understand the participants' survey responses and deepen the study's spectrum. The questions asked in the interview include:

- Strategies for incorporating renewable energy and modern power systems into the curriculum.
- Practices implemented to ensure curriculum relevance to industry needs.
- Examples of areas well-aligned and not well-aligned with industry needs.
- Adaptations of the curriculum in response to energy sector changes and policy shifts.
- Challenges faced in aligning curriculum with evolving industry needs, including barriers to updating the curriculum.
- Perspectives on the Policy – Pedagogy – Practice model in engineering education and its use in aligning policy, industry needs, and curriculum.
- Additional factors to consider in the interplay between national energy policy, the energy industry, and engineering education.
- Key skills and knowledge areas essential for graduates in the next 5-10 years considering the energy industry's trajectory.

4. Data analysis

4.1. Quantitative data

4.1.1. Industry survey

A total of 25 responses were received from the industry survey. This study engaged a diverse range of stakeholders from the Australian energy sector. Participants' organizations operate in specific areas of the electric power industry, including:

- Consulting services,
- Energy regulatory authorities,
- Energy storage solution providers,
- Energy market analysts/operations,
- Energy equipment manufacturing and sales,
- Governmental energy departments/agencies,
- Power transmission infrastructure providers,
- Renewable energy providers,
- Research and development departments, and
- Utility companies.

All participants are seasoned professionals in the electric power industry. Specifically, twelve participants (48%) have 3-7 years of industry experience, seven (28%) have between 7-10 years, and six (24%) have worked for over ten years. This experience makes them well-equipped to provide insights into the authentic demands of the industry and ensures a deep understanding of industry needs. As for their roles, the group combines a diverse range of positions as listed below. A summary of the survey responses can be seen in Table I.

- 7 executive managers,
- 7 senior engineers,
- 3 researchers,
- 2 policymakers,
- 2 owners of small to medium enterprises,
- 2 individuals in workforce training roles,
- 1 human resource officer, and
- 1 project manager.

Table I Industry participants' perspectives.

Aspect surveyed	**% of respondents**	**Description of responses**
Interaction with students/graduate Engineers	80%	Very frequently /Frequently/Occasionally
	20%	Rarely
	0%	Very rarely
Knowledge and technical skill level of recent graduates	56%	Good/Excellent
	40%	Average/Fair
	4%	Poor/Not sure
Curriculum alignment with industry needs	92%	Completely/Very/Moderately aligned
	8%	Slightly
	0%	Not at all

Aspect surveyed	% of respondents	Description of responses
Recruitment requirements change	64%	Completely/Very much
	28%	Moderately
	8%	Slightly
	0%	Not at all
Impact of national energy policy on expectations of new hires	92%	Completely/Very/Moderately impact
	8%	Slightly impact
	0%	No impact at all
Impact of energy policies on positions/job opportunities	84%	Completely/Very/Moderately impact
	16%	Slightly impact
	0%	No impact at all
Avenues for feedback to educational institutions	48%	Moderate/Slight
	36%	Very/Completely
	16%	Not at all
Collaboration with educational institutions	60%	Sometimes/Rarely/Never
	40%	Always/Often

The responses highlight varied levels of industry engagement with higher education institutions regarding graduate engineer requirements and curriculum relevance in the following aspects:

- Industry views on new graduates' knowledge and technical skills are predominantly positive.
- The curriculum is generally seen as well aligned with industry needs, although not completely.
- Energy policies significantly affect expectations for new hires and create specific job opportunities within the energy sector.
- While a combined majority of industry participants indicate some level of feedback avenues and collaboration with universities, the common responses point to only a slight avenue for feedback and occasional collaboration.

These findings imply that while there are connections between industry and educational institutions, there is potential for strengthening and increasing the frequency of these interactions to ensure that graduate engineers are well-prepared for industry demands.

4.1.2. Academic survey

A total of 10 responses were received from the academic survey. Eight of these respondents are from electrical engineering, while the remaining two are academic staff members from other disciplines with teaching specializations pertinent to energy systems. Among the participants, 60% have over ten years of experience teaching courses relevant to energy systems. The remaining 40% are fairly distributed across less experienced brackets, with 20%

having 4-7 years and 20% having 8-10 years of teaching experience. A summary of the survey responses can be seen in Table II.

Table II Engineering educators' perspectives.

Aspect surveyed	Percentage of respondents	Description of responses
Industry and government engagement	60%	Very/Extremely extensive
	40%	Moderately extensive
	0%	Not extensive at all/Slightly extensive
Curriculum alignment with industry needs	30%	Aligning very well
	40%	Moderately well
	30%	Slightly well
	0%	Not well at all/Extremely well
Curriculum comprehensiveness	50%	Fairly comprehensive
	10%	Extremely comprehensive
	20%	Neither comprehensive nor lacking
	20%	Somewhat lacking
	0%	Extremely lacking
Students' knowledge and skills upon graduation	80%	Average/Fair
	20%	Excellent/Good
	0%	Poor
Importance of teaching industry-specific skills	60%	Very/Extremely important
	40%	Moderately important
	0%	Not important at all/Slightly important
Importance of fundamental knowledge	70%	Extremely important
	30%	Very important
	0%	Not important at all/Slightly important/Moderately important
Likelihood of integrating new topics	40%	Extremely/Somewhat likely
	60%	Neutral/Somewhat unlikely
	0%	Extremely unlikely

Aspect surveyed	Percentage of respondents	Description of responses
Frequency of course content updates	60%	At least once a year (Once a year/Twice a year/More than twice a year/Continuously throughout the term)
	40%	Less than once a year
Consultation with industry professionals	50%	Annually
	50%	Less than once a year
	0%	Twice a year/More than twice a year/Continuously throughout the year
Influence of national energy policy	80%	At least a moderate impact
	20%	Slight influence
	0%	Not at all
Understanding of national energy policy	100%	Very/Extremely well
	0%	Not well at all/Slightly well/Moderately well

Key findings from the academic survey are analyzed below:

- Educators report a high level of engagement with industry and government.
- A varied perception of how well the curriculum aligns with industry needs is demonstrated, highlighting both successes and areas for improvement.
- Only half of the educator participants consult with industry professionals annually for course renewal. Yet the others do so less frequently.
- The influence of national energy policy on curriculum development is acknowledged.
- A strong emphasis on fundamental knowledge is shown, with a varied but notable interest in incorporating industry-specific tools into education.

These insights reveal a teaching cohort in energy systems with substantial industry engagement and a varied approach to curriculum development. While there is a consensus on the importance of fundamental knowledge, the variability in curriculum updating practices and the frequency of industry consultations suggests potential areas for closer alignment with evolving industry standards and policy developments.

4.2. Qualitative interview data

In total, sixteen interviews were conducted with industry professionals from various departments within the energy sector. These participants represent a broad spectrum of key institutions and organizations in the Australian energy industry. The diversity of our sample demonstrates the robustness of our qualitative data. The sampling strategy ensures that one group is not overly sampled, mitigating the risk of biased results. Participants are recruited from the following organizations and institutions. Detailed introductions to these organizations and institutions are provided in the Appendix.

- Australian Energy Market Operator (AEMO)
- Transgrid
- Ausgrid
- Western Power
- Endeavour Energy
- Energy Queensland
- Clean Energy Council
- Centre for New Energy Technologies
- Race 2030
- PSC
- DIgSILENT
- KMPG
- Sydney Trains

Thematic analysis was employed to interpret the interview data. The process involves identifying recurring patterns or themes in the data using Nvivo, which helps understand the key enablers and barriers identified by the stakeholders. The themes derived from this analysis inform the development of the model and guide our recommendations for improving the alignment between energy policy, industry needs, and the curriculum. The thematic analysis yielded various themes and subthemes, which were organized according to their relevance to the three components of the "3P" model.

4.3. Timeline of energy policies

Relevant government documents and reports [23-30] were reviewed to gain a comprehensive understanding of the policy changes in the global and national energy sectors. These documents provide valuable context and background information to map the timeline of policy transitions and understand their implications for the energy industry and engineering education. A timeline in Figure 3 illustrates the changes in global and domestic energy policy and their correlation with the pace of the curriculum update in energy systems at the University of New South Wales (UNSW), for example.

The key updates in the curriculum are designated as (a) to (g) to demonstrate the detailed curriculum developments outlined below:

(a) Introduction of *Smart Grids and Distribution Networks* as a new postgraduate course.

(b) Launch of a new Year 3 course, *Distributed Energy Generation*.

(c) Integration of microgrid and controller design using MATLAB/Simulink in *Design Proficiency*.

(d) Addition of lab sessions in *Distributed Energy Generation* for hands-on experience in modeling distributed wind, photovoltaic (PV), and battery energy storage systems (BESS).

(e) Inclusion of PSCAD software in simulation laboratories for *Power System Analysis*.

(f) Incorporation of tutorial-lab sessions in the first-year course *Electrical Circuit Fundamentals* to introduce renewable energy concepts.

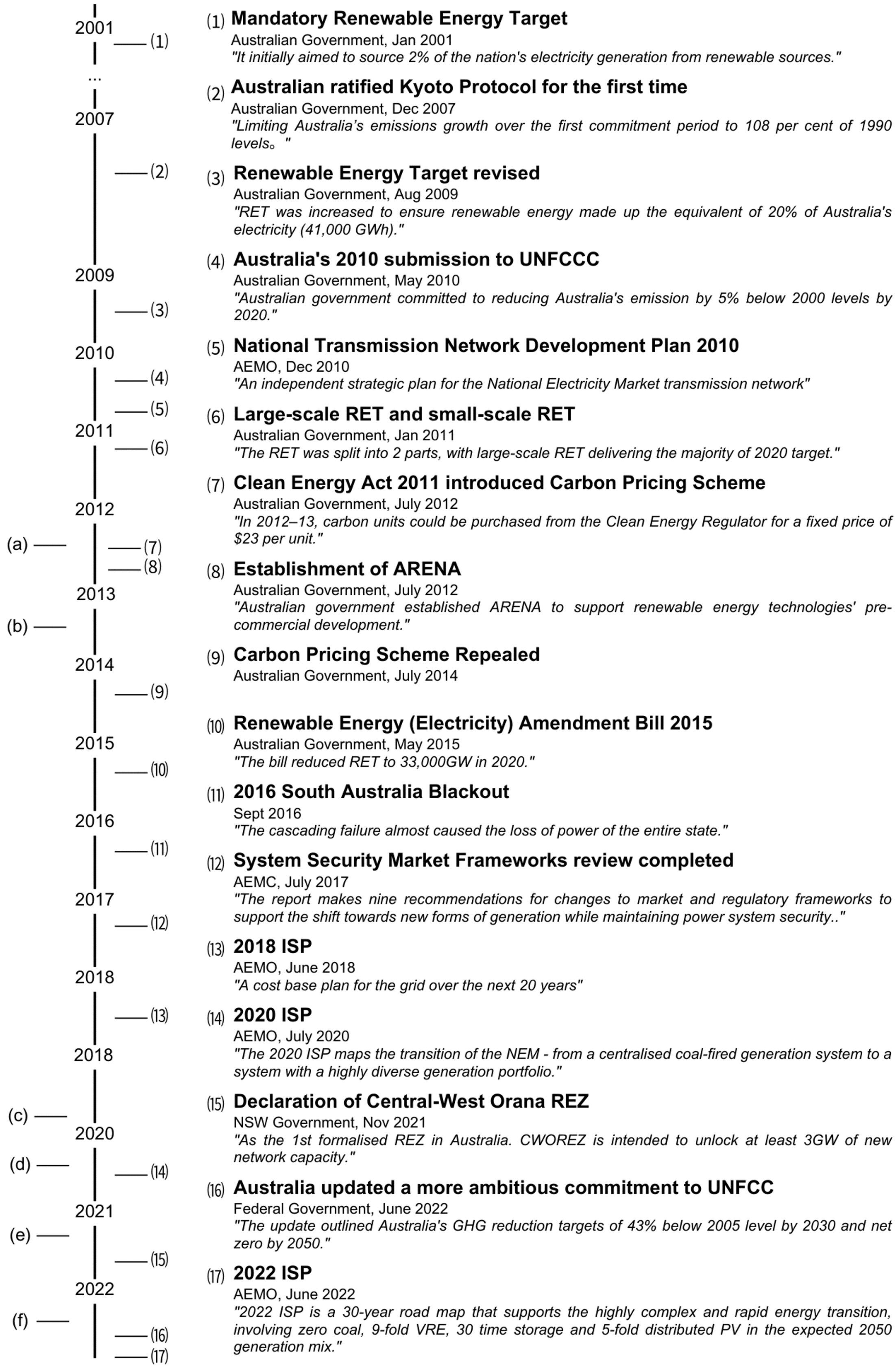

Figure 2 Comparison of curriculum update and energy policy milestones timeline.

Two main observations are made. First, curriculum development tends to lag behind energy policy and industry advancements, with significant course updates occurring in the early 2020s after notable changes in the industry. Second, the curriculum renewal influenced by energy policies spans all program levels, from first-year undergraduate to postgraduate courses. Introductory courses focus on fundamental knowledge and concepts in energy systems, while advanced courses offer practical, industry-aligned skills, preparing students for the workforce. This comprehensive curriculum development ensures students acquire the necessary skills for evolving industry demands.

4.4. Proposed model

For a more comprehensive insight, the "3P" model is further elaborated by detailing the enablers and barriers uncovered in our data analysis. This involves an in-depth exploration of the interactions between each pair of components – Policy and Pedagogy, Pedagogy and Practice, and Policy and Practice – as depicted in Figure 3.

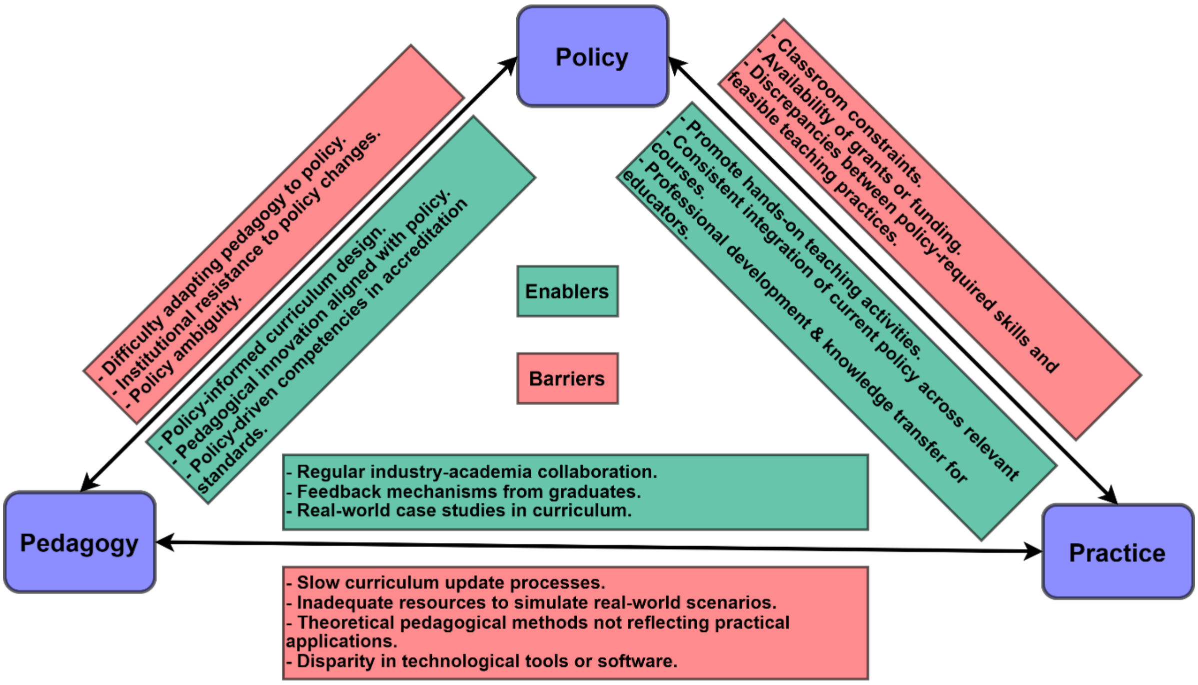

Figure 3 Interactions and dynamics within the "3P" Model - enablers and barriers.

In the model, enablers are factors and mechanisms that facilitate the integration and alignment of the "3P" components toward achieving an adaptable, industry-relevant engineering curriculum. Enablers help overcome obstacles during curriculum development and promote effective communication and collaboration responsive to industry needs and policy changes. For example, in the dynamic interplay between Policy and Pedagogy, "Policy-informed curriculum design" emerges as one of the crucial enablers. This concept refers to the deliberate shaping of the curriculum to incorporate competencies, skills, and knowledge areas emphasized within the latest energy policies. If national energy policies increasingly prioritize the role of energy storage in renewable energy integration, a policy-informed curriculum design would integrate courses and modules focused on battery energy storage systems and their impact on grid-connection studies. This approach enables educators to directly translate policy priorities into educational content, ensuring that students are well-prepared for the roles the industry will need them to play, making them more competitive in the job market.

On the other hand, barriers are defined as challenges or obstacles that hinder or disrupt the seamless integration of the "3P" components. These include factors that make it challenging to update educational strategies in line with industry requirements and policy objectives. Barriers may involve institutional inertia, resource limitations, and policy ambiguities. In the Pedagogy ↔ Practice relationship, "Slow curriculum update processes," is one of the barriers that impedes the timely reflection of industry advancements and technological innovations in the curriculum. This delay in curriculum updates can lead to a misalignment between the skills taught in educational institutions and those demanded by the energy sector. For instance, the rapid advancement in smart grid technologies demands a workforce adept in the area. However, if the curriculum updates lag behind these technological shifts, graduates may find themselves lacking critical skills such as data analytics for energy systems. This skill gap can hinder their employability and limit their ability to contribute effectively to industry innovation and adaptation to policy changes. Moreover, this misalignment could potentially slow the industry's progress toward achieving policy goals related to energy sustainability and security, as the incoming workforce is not fully prepared to implement these advanced technologies.

4.4.1. Policy ↔ Pedagogy

Enablers

- Policy-informed curriculum design refers to the direct influence of current policy standards on the structure of the curriculum. This means that the curriculum is consciously shaped to incorporate the skills, knowledge areas, and competencies emphasized within the latest energy policies, ensuring that graduates are prepared to meet the demands of the industry.
- Pedagogical innovation aligned with policy encompasses developing new teaching methods that arise as a direct response to changes in policy. For instance, if a new policy emphasizes sustainability, educators might adopt project-based learning that focuses on renewable energy projects.
- Policy-driven competencies in accreditation standards imply that the criteria used to accredit educational programs are derived from competencies outlined in policy documents. This ensures the programs produce graduates equipped to work within the current policy framework.

Barriers

- Difficulty adapting pedagogy to policy highlights educators' challenges in updating their teaching methods and content to stay aligned with frequently evolving energy policies. This can be due to the inertia of established educational practices or the time it takes to develop and implement new curricula.
- Institutional resistance to policy changes points to the hesitancy within educational organizations to modify existing curricula. This resistance can stem from bureaucratic processes, the perceived risk of frequent changes, or the effort required to realign programs with new policy directives.
- Policy ambiguity can lead to uncertainties in curriculum development, especially when policies are vague, lack specificity, or are subject to frequent changes. Educators may struggle to interpret and integrate such policies into the curriculum effectively.

4.4.2. Pedagogy ↔ Practice

Enablers

- Regular industry-academia collaboration involves active engagement between educational institutions and industry partners. This collaboration helps ensure that the teaching methods and content are relevant and current to current industry practices and challenges.

- Feedback mechanisms from graduates leverage the insights of alumni who are now industry professionals to refine and update the curriculum. Their real-world experience can inform educators about the efficacy of the teaching methods and the relevancy of the skills taught.
- Real-world case studies in the curriculum bring practical, industry-relevant challenges into the classroom, allowing students to work on issues that professionals in the field are currently facing, thereby enhancing the practical applicability of their learning.

Barriers

- Slow curriculum update processes refer to the lag in updating educational content to reflect the rapid changes occurring within the industry, which can leave graduates underprepared for current professional environments.
- Inadequate resources to simulate real-world scenarios denote the lack of tools, equipment, and software necessary to accurately recreate and study real-world industry scenarios within an educational setting, leading to a gap between theoretical knowledge and practical skills.
- Theoretical and pedagogical methods that do not reflect practical applications highlight an overemphasis on theory in the curriculum, which can result in graduates lacking hands-on experience and practical skills.
- Disparity in technological tools or software indicates a mismatch between the technology used in educational settings and what is currently used in the industry, potentially disadvantaging students when they enter the job market.

4.4.3. Policy ↔ Practice

Enablers

- Promote hands-on teaching activities and ensure that practical experience is a critical component of the educational process, influenced by the practical skills and competencies highlighted in policy.
- Consistent integration of current policy across relevant courses means that all courses within a program consistently reflect and incorporate current policies, leading to a cohesive and policy-informed educational experience.
- Professional development and knowledge transfer for educators involves providing teachers and faculty with continuous training and updates on policy changes, ensuring that they remain knowledgeable and can effectively translate these policies into their teaching.

Barriers

- Classroom constraints such as time limitations or logistical challenges can impede the implementation of policy-informed teaching practices.
- Availability of grants or funding affects the resources available for educators to introduce new, policy-compliant practices, with financial constraints often limiting what can be achieved.
- Discrepancies between policy-required skills and feasible teaching practices refer to the gap between the skills that policy dictates should be taught and those that can realistically be developed through current pedagogical methods due to various constraints.

These enablers and barriers provide a comprehensive framework for understanding the interactions between policy, pedagogy, and practice in educational settings. They highlight the key areas where improvements can be made to align these three aspects better and overcome challenges in the process.

5. Transferability and recommendations

5.1. Transferability of the "3P" model in other disciplines

In engineering disciplines, the policy level drives industries, and emerging trends in national policies can further impact the curriculum needed at higher education institutions. In this section, the emerging trends and topics in other disciplines are summarised, and further work can be carried out to update the curriculum in these areas, considering the upcoming evolution of relevant industries as well as the requirements (knowledge base and skillset) of the workforce. To illustrate, an analysis was conducted across various representative engineering disciplines. This examination aims to explore the potential for transferring and adapting the model across different fields within engineering. Table III provides a concise summary of how the "3P" model can be transferable to other disciplines, with each example illustrating the interplay between policy, pedagogy, and practice:

Table III. Transferability of the "3P" model in typical engineering disciplines.

Discipline	"3P" components (Policy – Pedagogy – Practice)	
Biomedical Engineering	**Policy**	Regulations on healthcare technology and data privacy.
	Pedagogy	Teaching medical device regulations, data privacy laws, and clinical trial methodologies.
	Practice	Implementing case studies on medical device design, simulations of data privacy scenarios, and hands-on clinical trial projects.
Civil and Environmental Engineering	**Policy**	Climate change, sustainability, infrastructure policies.
	Pedagogy	Focusing on sustainable construction materials, urban planning, and international environmental treaties.
	Practice	Incorporating project-based learning for sustainable building designs and workshops on applying environmental treaties in urban development.
Chemical Engineering	**Policy**	Environmental protection, chemical safety.
	Pedagogy	Emphasizing green chemistry principles, industrial waste management, and sustainable chemical processes.
	Practice	Laboratory experiments in green chemistry and field trips to waste management facilities will be used to demonstrate eco-friendly processes.

Discipline	"3P" components (Policy – Pedagogy – Practice)	
Computer Science and Engineering	**Policy**	Data privacy, cybersecurity, AI regulations.
	Pedagogy	Covering cybersecurity, data protection regulations, and AI ethics.
	Practice	Conducting coding workshops focusing on data protection, cyber security simulations, and debates on AI ethics.
Telecommunications	**Policy**	Net neutrality, data privacy, spectrum allocation.
	Pedagogy	Teaching about 5G technologies, spectrum management, and net neutrality implications.
	Practice	Organizing hands-on activities in 5G technology implementation and spectrum management exercises.
Mineral and Energy Resources Engineering	**Policy**	Mining safety, environmental protection.
	Pedagogy	Sustainable mining practices, automation in mining, and environmental impact assessments.
	Practice	Implementing field visits to mining sites and simulations of automated mining operations.
PV and Renewable Energy Engineering	**Policy**	Renewable energy targets, carbon pricing.
	Pedagogy	Teaching advanced PV systems, energy storage technologies, and grid integration.
	Practice	Conducting laboratory experiments on PV systems and group projects on renewable energy integration.
Mechanical and Manufacturing Engineering	**Policy**	Manufacturing safety, environmental protection.
	Pedagogy	Covering manufacturing safety, preventive maintenance, and energy-efficient machinery design.
	Practice	Engaging students in machinery safety audits and design projects for energy-efficient machines.

5.2. Recommendations

The recommendations listed below can be implemented to create a curriculum framework that is responsive to current industry demands and policy changes and proactive in anticipating future developments in the energy sector.

- Facilitate regular collaboration among stakeholders: Regular collaboration among policymakers, academia, and industry ensures better alignment and strengthens the "3P" framework. Incentivizing industry-academia collaborations can enhance the practical aspect of education, promoting a hands-on learning environment.

- Clarify policies and expectations: Policies should be clear and specific, outlining the expected workforce numbers, required skills, and demand. Actionable and policy-informed expectations reduce ambiguity and ease the implementation in academic and industry sectors. This clarity enables educators to create specific course content and develop feasible assessment methods. Establishing feedback mechanisms allows stakeholders (e.g., recent graduates) to share insights and concerns, improving the "3P" model's responsiveness.
- Augment resources for academic institutions: Investing in tools and resources that align pedagogical practices with industry standards prepares students for their careers. Collaborative curriculum design and resource sharing, involving industry professionals in curriculum planning and delivery, keep educational content relevant and practical.
- Emphasize continuous professional development: Ongoing professional development opportunities targeting educators should be offered to ensure that the curriculum remains in sync with evolving industry needs, reinforcing the pedagogical aspect of the "3P" model. Including academics in policy drafting for workforce development leads to more balanced and grounded policies that reflect the realities of both academia and industry.
- Conduct periodic curriculum renewal mechanisms: Regularly reviewing and updating curricula according to the accreditation standards ensures their alignment with industry practices and relevant policies, maintaining their relevance and effectiveness.

These recommendations aim to create a more dynamic, interconnected "3P" framework, which can further facilitate a more sustainable workforce flow.

6. Conclusion and future work

This paper investigates the alignment of engineering education with evolving national energy policies and industry demands and proposes a "3P" (Policy, Pedagogy, Practice) model. The model focuses on identifying the enablers and barriers when developing the current engineering curricula to respond to the future needs of the energy sector. The research contributions could enable education authorities and academics to identify and bridge the gap between the current curriculum framework at the program level and the industry demand, considering the latest national policy. The model's generalizability is demonstrated, indicating its potential for adaptation across other areas. The findings contribute to developing an industry-oriented curriculum framework and provide practical recommendations for policymakers, educators, and industry stakeholders, which are critical for developing a workforce equipped to meet the demands of grid modernization.

This study primarily focuses on presenting a conceptual framework that supports the inclusion of policy considerations when performing course renewals in engineering disciplines. Future research could build on this foundation to identify potential strategies and provide exhaustive evidence on their efficacy with further validation. These discipline-specific studies have the potential to offer more concrete recommendations for educators in different disciplines.

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References

[1] R. A. Dias, M. Rios de Paula, P. M. Silva Rocha Rizol, J. A. Matelli, C. Rodrigues de Mattos, and J. A. Perrella Balestieri, "Energy education: Reflections over the last fifteen years," *Renewable and Sustainable Energy Reviews,* vol. 141, p. 110845, 2021/05/01/ 2021, doi: https://doi.org/10.1016/j.rser.2021.110845.

[2] W.-J. Lee, "Workforce Development to Meet the Need for Grid Modernization [President's Message]," *IEEE Industry Applications Magazine,* vol. 28, no. 5, pp. 5-6, 2022.

[3] H. Chai, J. Ravishankar, S. Krishnan, and M. Priestley, "Work-in-Progress: A Holistic Approach to Bridging the Gap between Power Engineering Education and Electric Power Industry," presented at the 2022 IEEE Global Engineering Education Conference (EDUCON), Tunis, Tunisia, 28-31 March 2022.

[4] N. Munasinghe, H. Chai, and J. Ravishankar, "Board 91: Work-in-Progress: A Systematic Gap Analysis of the Australian Power Engineering Curriculum," in *2023 ASEE Annual Conference & Exposition*, 2023.

[5] D. R. Garrison and N. D. Vaughan, *Blended learning in higher education: Framework, principles, and guidelines*. John Wiley & Sons, 2008.

[6] K. A. Walz, M. Slowinski, and K. Alfano, "International Approaches to Renewable Energy Education--A Faculty Professional Development Case Study with Recommended Practices for STEM Educators," *American Journal of Engineering Education,* vol. 7, no. 2, pp. 97-116, 2016.

[7] B. Durrans, J. Whale, and M. Calais, "Benchmarking a sustainable energy engineering undergraduate degree against curriculum frameworks and pedagogy standards from industry and academia," *Energies,* vol. 13, no. 4, p. 822, 2020.

[8] P. Jennings, "New directions in renewable energy education," *Renewable energy,* vol. 34, no. 2, pp. 435-439, 2009.

[9] R. Belu, R. Chiou, and L. Cioca, "Embedding renewable energy concepts into engineering curriculum," in *2017 ASEE Annual Conference and Exposition, Columbus, Ohio, USA*, 2017.

[10] T. Carroll, "Energy: options for the future. Curriculum development project for high school teachers. Final report.[Packet]," State Univ. of New York, Stony Brook (USA), 1978.

[11] N. Mohan, W. P. Robbins, and B. F. Wollenberg, "Power systems education based on CUSP™-curriculum," *IEEE Transactions on Power Systems,* vol. 29, no. 4, pp. 1896-1902, 2014.

[12] G. F. Reed and W. E. Stanchina, "Smart grid education models for modern electric power system engineering curriculum," in *IEEE PES General Meeting*, 2010: IEEE, pp. 1-5.

[13] J. E. Tate, J. Sebestik, and T. Overbye, "Collaboration and dissemination efforts related to pre-university power lessons," in *2008 IEEE Power and Energy Society General Meeting-Conversion and Delivery of Electrical Energy in the 21st Century*, 2008: IEEE, pp. 1-1.

[14] F. R. Shahroury, I. Abuishmais, and H. H. Ahmad, "Development of Renewable Energy Course for Electrical Engineering Program," in *2023 46th MIPRO ICT and Electronics Convention (MIPRO)*, 2023: IEEE, pp. 1538-1542.

[15] R. B. Bass, "A Bachelors degree program in renewable energy engineering," in *Proceedings. Frontiers in Education. 36th Annual Conference*, 2006: IEEE, pp. 13-16.

[16] K. A. Rosentrater and Y. Al-Kalaani, “Renewable energy alternatives–a growing opportunity for engineering and technology education,” *The Technology Interface,* vol. 6, no. 1, pp. 1-9, 2006.
[17] P. Jennings and C. Lund, “Renewable energy education for sustainable development,” *Renewable Energy,* vol. 22, no. 1-3, pp. 113-118, 2001.
[18] R. F. Naill, “A system dynamics model for national energy policy planning,” *System Dynamics Review,* vol. 8, no. 1, pp. 1-19, 1992.
[19] G. Bersalli, P. Menanteau, and J. El-Methni, “Renewable energy policy effectiveness: A panel data analysis across Europe and Latin America,” *Renewable and Sustainable Energy Reviews,* vol. 133, p. 110351, 2020.
[20] H. Yu, H. Chai, and J. Ravishankar, “Identifying the Needs of Electric Power Industry through Online Job Ads: A Mixed-methods Approach,” in *2023 ASEE Annual Conference & Exposition*, 2023.
[21] R. K. R. Karduri and C. Ananth, “The Economics of Transitioning to Renewable Energy Sources,” *This paper has been published in the International Journal of Advanced Research In Basic Engineering Sciences and Technology (IJARBEST) DOI,* vol. 10, 2023.
[22] P. Barman *et al.*, “Renewable energy integration with electric vehicle technology: A review of the existing smart charging approaches,” *Renewable and Sustainable Energy Reviews,* vol. 183, p. 113518, 2023.
[23] A. Kent and D. Mercer, “Australia's mandatory renewable energy target (MRET): an assessment,” *Energy Policy,* vol. 34, no. 9, pp. 1046-1062, 2006.
[24] K. Crowley, “Is Australia faking it? The Kyoto Protocol and the greenhouse policy challenge,” *Global Environmental Politics,* vol. 7, no. 4, pp. 118-139, 2007.
[25] S. Valentine, “Braking wind in Australia: A critical evaluation of the renewable energy target,” *Energy Policy,* vol. 38, no. 7, pp. 3668-3675, 2010.
[26] A. E. M. Operator, “National transmission network development plan,” *Australian Energy Market Operator,* 2011.
[27] J. Cludius, S. Forrest, and I. MacGill, “Distributional effects of the Australian Renewable Energy Target (RET) through wholesale and retail electricity price impacts,” *Energy Policy,* vol. 71, pp. 40-51, 2014.
[28] B. Zeller and M. Longo, “Australia's Clean Energy Act: A New Measure in the Global Carbon Market,” *Loy. U. Chi. Int'l L. Rev.,* vol. 10, p. 179, 2012.
[29] L. Byrnes, C. Brown, J. Foster, and L. D. Wagner, “Australian renewable energy policy: Barriers and challenges,” *Renewable energy,* vol. 60, pp. 711-721, 2013.
[30] A. E. M. Operator, “2022 Integrated System Plan for the National Electricity Market,” 2022.

Appendix

- **Australian Energy Market Operator (AEMO)**: Responsible for operating Australia's national electricity and gas markets and systems, AEMO plays a critical role in ensuring sustainable energy supply to both residential and industrial consumers.
- **TransGrid**: TransGrid is the network service provider of NSW and ACT, which builds and maintains the most important electricity network in Australia, providing the backbone of the National Electricity Market. They play a key role in the energy infrastructure, connecting generators, distributors, and end users.
- **Ausgrid**: The largest electricity distributor in New South Wales, Australia. They manage a vast network of poles, wires, substations, and meters to deliver electricity to homes and businesses.
- **Western Power**: This is a Western Australian State Government-owned corporation responsible for building, maintaining, and operating an electricity network connecting consumers to a range of energy sources.
- **Endeavour Energy**: An electricity distribution company servicing Western Sydney, the Blue Mountains, the Southern Highlands, and the Illawarra region of New South Wales, Australia.
- **Energy Queensland**: A state government-owned corporation in Queensland, Australia. They are involved in electricity distribution and retail, ensuring efficient energy delivery to homes and businesses across the region.
- **Clean Energy Council**: Australia's renewable energy association, advocating for and supporting the growth of clean energy business and deployment in Australia, including solar, wind, energy storage, and more.
- **Centre for New Energy Technologies (C4NET)**: An innovative hub focused on researching and developing new energy technologies. It offers a new model for a new energy world - an innovative, membership-based organization spanning Victoria's new energy technology industry, university, and government sectors.
- **Race 2030**: A collaborative initiative to accelerate the development and adoption of cutting-edge technologies to meet Australia's energy needs by 2030, focusing on sustainability and innovation in the energy sector.
- **DIgSILENT**: An independent software and consulting company specializing in electrical power systems analysis. They are known for their advanced software solutions (PowerFactory) for engineering and operational studies in electrical power systems.
- **PSC:** An electrical engineering consultancy firm providing expert services and advice in power system planning, design, and operation.
- **KMPG**: A global network of professional firms providing consulting services, including power systems.
- **Sydney Trains**: Responsible for managing Sydney's suburban train network. They ensure reliable and efficient train services across the city and its suburbs.