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Look at Risk/Benefit of Energy Options for the Transition:

A Systematic Review of Transition to Wind Energy in Norway after the Paris Agreement

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Engineering Risk Analysis and Management

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Abstract

This thesis investigates the expert discussion on the risks and benefits of wind energy in Norway after the 2016 Paris Agreement, assessing its role as a key source for achieving an energy transition. Through a systematic literature review across relevant databases, a notable gap was identified – no studies directly addressed this specific research topic for the Norwegian context. However, insights from related literature provided a broader understanding of renewable energy transitions, with particular relevance to wind energy development in Norway.

The review highlighted various factors influencing wind energy adoption, including policy incentives, technical obstacles, environmental impacts, public acceptance challenges, economic drivers, and technological advancements. While these studies offered valuable context, they lacked explicit framing within structured risk assessment and evaluation frameworks, failing to comprehensively consider complexity, uncertainty, and ambiguity as emphasized by risk science theories.

The absence of focused research aligns with the study's primary finding – a significant gap in the academic discourse on evaluating the risk-benefit balance of wind energy specific to Norway's geographical, social, and economic contexts. This gap underscores the need for future interdisciplinary studies that integrate risk science methodologies, conduct longitudinal analyses, and comparatively examine wind energy development across similar regions.

By highlighting this critical literature gap and proposing future research directions, this thesis contributes to the ongoing discourse on renewable energy transitions. It emphasizes the importance of focused, risk-based analyses to harness wind energy's potential while mitigating associated risks, ultimately supporting Norway's sustainable energy goals and the global transition towards renewable sources.

Keywords: Risk and Benefit, Energy Transition, Wind Energy, Norway

1. Introduction

The energy sector is the leading contributor to greenhouse gas (GHG) emissions, and according to Huang and Liu (2021), making the low-carbon energy transition a global imperative (Saraji & Streimikiene, 2023). GHG emissions significantly impact global warming and climate change, which are among the most critical issues facing the world today. Based on works by Andrews-Speed (2016), Farsaei et al (2022) and Laakso et al (2021), transitioning to a low-carbon energy system is essential to address the dual challenges of sustainable development and climate change, necessitating rapid and radical socio-technical changes (Saraji & Streimikiene, 2023). The Paris Agreement, for instance, calls for a global 60%–80% reduction in GHG emissions by 2050, requiring the widespread adoption of low-carbon products and services (Saraji & Streimikiene, 2023).

Based on Johansen and Johra (2022), the low-carbon energy transition is not just a technological shift but a socio-technical one that requires addressing multiple challenges and barriers simultaneously (Saraji & Streimikiene, 2023). While these challenges can be addressed using various approaches, a crucial perspective that needs further exploration is the risk-benefit analysis of energy transition process. This perspective can be essential to balance the potential risks and benefits associated with energy options (Renewable energy sources) for energy transition.

Wind energy has emerged as one of the key renewable energy sources in this transition, particularly, in those regions with high potential of acquisition to this type of energy. Regarding this, the focus of expert discussions on the risks and benefits of energy transition can be crucial for understanding the complexities of the energy transition to wind energy. In Norway, the potential for wind energy development is significant due to its favourable geographic and climatic conditions. So, this thesis aims to investigate these discussions, shedding light on how experts perceive the risks and benefits associated with the transition to wind energy in Norway. Understanding these perspectives can be vital for informed policy-making and stakeholder decision-making.

In addition, this research can provide a comprehensive understanding of the current discourse, identify gaps in knowledge, and suggest directions for future research. The findings can support Norway’s renewable energy goals and contribute to global efforts to transition to sustainable energy sources.

2. Literature Review

2.1 Addressing the Risk Concepts

As this thesis aims to investigate the discussions of experts regarding the risks and benefits of wind energy in Norway, it is essential to establish a clear understanding of the fundamental risk concepts. These concepts serve as the foundation for comprehending how risks are perceived, evaluated, and communicated within the academic discourse. By examining the definitions and underlying principles of risk, we can better analyze and interpret the expert perspectives presented in the literature.

2.1.1 Definitions of the Risk Concepts

Table 1 presents several definitions for risk, all based on the same ideas illustrated in Figure 1 (Aven & Thekdi, 2022, p.10-11).

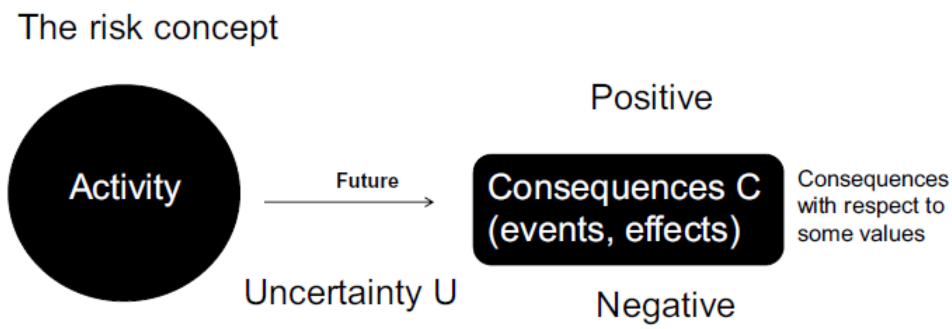

Figure 1: The basic features of the risk concept (based on Aven & Thekdi, 2020)

The activity that is considered in this Figure (for example, driving a car from one place to another), will lead to some consequences seen in relation to some values (such as human lives and health). The consequences could, for example, be some injuries and loss of lives. There is at least one consequence or outcome that is considered negative or undesirable. Looking forward in time, there are uncertainties what the consequences will be (Aven & Thekdi, 2022, p.10).

Definition 1: Risk: The potential for undesirable consequences **Definition 2** Risk: The consequences C of the activity and associated uncertainties U Risk: (C,U) Risk: (A,C,U), where A is an event (or a set of events) and C the consequences given the occurrence of A **Definition 3** Risk: The deviation D from a 'reference value' r, and associated uncertainties U Risk: (D,U)

Table 1: Definitions of the Risk (based on Aven & Thekdi, 2020)

In the definition 1, The term 'potential' relates to the consequences but points also to the uncertainties.

The definition 2 is appealing, as it explicitly incorporates both consequences and uncertainties, which can be seen as the two key components of the risk concept.

In the definition 3, risk captures the potential for a deviation from the planned level, often with a focus on values below this level (Aven & Thekdi, 2022, p.10-11).

By exploring these definitions, we establish a common understanding of risk as a concept that encompasses potential consequences, uncertainties, and deviations from desired outcomes. This foundation can guide our analysis of how experts perceive and discuss the risks associated with wind energy development in Norway, allowing us to critically examine the various perspectives and arguments presented in the literature.

2.1.2 Complexity, Uncertainty and Ambiguity in Risk

Each risk class is indicative of a different pattern of Complexity, Uncertainty and Ambiguity (Renn, 2008, p.165).

Complexity refers to the difficulty of identifying and quantifying causal links between a multitude of potential causal agents and specific observed effects (Renn, 2008, p.75).

Uncertainty is different from complexity, but most often results from an incomplete or inadequate reduction of complexity in modelling cause–effect chains (Renn, 2008, p.75).

In SRA (Society for Risk Analysis Glossary) (Aven et al, 2018), two overall qualitative definitions are given as for Uncertainty.

a) For a person or a group of persons, not knowing the true value of a quantity or the future consequences of an activity.
b) Imperfect or incomplete information/knowledge about a hypothesis, a quantity, or the occurrence of an event

In relation to risk governance, Ambiguity is understood as "giving rise to several meaningful and legitimate interpretations of accepted risk assessments results" (Renn, 2008, p.77).

Risks that do not rank high on complexity, uncertainty or ambiguity are called routine or linear risks. They can be managed by means of risk–benefit analysis, risk–risk comparisons or other traditional instruments of balancing pros and cons (Renn, 2008, p.186).

2.1.3 Risk Handling: tolerability or acceptability

According to HSE (2001), the most controversial aspect of handling risks refers to the process of delineating and justifying a judgement about the tolerability or acceptability of a given risk. The term 'tolerable' refers to an activity that is seen as worth pursuing (for the benefit that it carries); yet it requires additional efforts for risk reduction within reasonable limits. The term 'acceptable' refers to an activity where the remaining risks are so low that additional efforts for risk reduction are not seen as necessary (Renn, 2008, p.149).

According to Renn (2008, p.149), "The distinction between tolerability and acceptability can thus be applied to a large array of risk sources. Tolerability and acceptability can be located in a risk diagram, with probabilities on the y-axis and extent of consequences on the x-axis. This is known as the 'traffic light model', representing acceptable risk in green, tolerable risk in amber and intolerable risk in red".

2.1.4 Judgements on acceptability and tolerability (Relevant to Risk Handling process)

Judgements on acceptability rely on two major inputs: values and evidence. What society is supposed to tolerate or accept can never be derived from looking at the evidence alone. Likewise, evidence is essential if we are to know whether a value has been violated or not (or to what degree). With respect to values and evidence we can distinguish three cases:

a) Ambiguity of evidence but not of values (interpretative ambiguity);

In those cases where there is unanimous agreement about the underlying values and even the threshold of what is regarded as tolerable or acceptable, evidence in the form of risk estimates may be sufficient to locate the risk within the traffic light diagram. A judgement can then best be made by those who have most expertise in risk and concern assessments, in which case it makes sense to place this task within the domain of appraisal. The judgement will thus be based on best scientific modelling of epistemic and aleatory uncertainties (Renn, 2008, p.151).

b) Ambiguity of values but not of evidence (normative ambiguity);

If the underlying values of what could be interpreted as tolerable, or acceptable, are disputed, while the evidence of what is at stake is clearly given and non-controversial, the judgement needs to be based on a discourse about values and their implications. Such a discourse falls clearly in the domain of risk management. A good example may be the normative implications of risks related to smoking. Science is very familiar with these risks, and there is little uncertainty and interpretative ambiguity about dose–effect relationships. Yet, there is considerable debate about whether smoking is tolerable or not (Renn, 2008, p.151, 153).

c) Ambiguities of values and evidence.

A third case arises where both the evidence and the values are disputed. This would imply that assessors should engage in an activity to find some common ground for characterizing and qualifying the evidence, and risk managers need to establish agreement about the appropriate values and their application. A good example for this third case may be the interpretative and normative implications of global climate change (Renn, 2008, p.151, 153).

2.1.5 Risk Characterization and Risk Evaluation (Relevant to acceptability and tolerability)

The process of judging the tolerability and acceptability of a risk can be structured into two distinct components: risk characterization and risk evaluation (Renn, 2008, p.153).

Risk characterization determines the evidence-based component for making the necessary judgement on the tolerability and/or acceptability of a risk (Renn, 2008, p.153).

According to Stern and Fineberg (1996), risk characterization includes tasks such as point estimates of risks; descriptions of remaining uncertainties (as undertaken, for instance, in climate change models or risk studies on endocrine disruptors); potential outcome scenarios, including social and economic implications; suggestions for safety factors to include inter-target variation; assurance of compatibility with legal prescriptions; risk–risk comparisons; risk–risk trade-offs; identification of discrepancies between risk assessment and risk perceptions, as well as of potential equity violations; and suggestions for reasonable standards to meet legal requirements (Renn, 2008, p.153-154).

Risk evaluation, determines the value-based component for making this judgement. In particular, evaluation is directed towards three different kinds of deliberations:

a) Deliberation on the results of risk characterization in consideration of wider social and economic factors (e.g. benefits, societal needs, quality-of-life factors, sustainability, distribution of risks and benefits, social mobilization and conflict potential), legal requirements and policy imperatives;
b) Weighing of pros and cons and trading-off of different (sometimes competing or even conflicting) preferences, interests and values;

c) Taking into account the individual and social benefits associated with the risk bearing technology or activity (Renn, 2008, p.153-154).

Below, Table 2 from Renn (2008, p.155) summarizes these two steps, which, in conclusion, are closely interrelated and may be merged if the circumstances require it. The list of indicators represents only a small selection of potential dimensions and is displayed here for illustrative purposes.

Assessment components	Definition	Indicators
1 **Risk characterization**	Collecting and summarizing all relevant evidence necessary for making an informed choice on tolerability or acceptability of the risk in question and suggesting potential options for dealing with the risk from a scientific perspective	**Risk profile:** • Risk estimates • Confidence intervals • Uncertainty measures • Hazard characteristics • Range of 'legitimate' interpretations • Risk perceptions • Social and economic implications **Judging the severity of risk:** • Compatibility with legal requirements • Risk–risk trade-offs • Effects on equity • Public acceptance **Conclusions and risk reduction options. Suggestions for:** • Tolerable risk levels • Acceptable risk levels • Options for handling risks
2 **Risk evaluation**	Applying societal values and norms to the judgement on tolerability and acceptability and, consequently, determining the need for risk reduction measures	• Choice of technology • Potential for substitution • Risk–benefit comparison • Political priorities • Compensation potential • Conflict management • Potential for social mobilization

Source: adapted from IRGC, 2005, p41

Table 2: Tolerability/ acceptability judgement

2.1.6 Link between Risk Characterization and Risk Evaluation

Since risk characterization and evaluation are closely linked and depend upon each other, it may even be wise to perform these two steps simultaneously in a joint effort by both assessors and risk managers (Renn, 2008, p.156).

As an example, the US regulatory system generally prefers to combine characterization and evaluation within organizations, whereas European risk managers typically keep these functions separate (Löfstedt & Vogel, 2001; Vogel, 2003).

2.1.7 Risk Characterization based on complexity, uncertainty, and ambiguity

The distinction between the three challenges of risk assessment (complexity, uncertainty, and ambiguity) can also assist assessors and managers in assigning, or dividing, the judgement task. If a given risk is characterized by high complexity, low remaining uncertainties and hardly any ambiguities (except for interpretative differences over an established scientific risk assessment result), it is wise to let the assessment team dominate the process of making tolerability/acceptability judgements. If, in contrast, the risk is characterized by major unresolved uncertainties and if the results lead to highly diverse interpretations of what they mean for society, it is advisable to let risk managers take the lead (Renn, 2008, p.156).

Making use of the distinction between complexity, uncertainty and ambiguity, it is possible to design generic strategies of risk management to be applied to risk classes. One can distinguish four classes for risk. Regarding this, the Table 3 shows risk characteristics and their implications for risk management (Renn, 2008, p.177, 182):

Knowledge characterization	Management strategy	Appropriate instruments	Stakeholder participation
1 'Linear' risk problems	*Routine-based* (tolerability/acceptability judgement) (risk reduction)	→ Applying 'traditional' decision-making • Risk–benefit analysis • Risk–risk trade-offs • Trial and error • Technical standards • Economic incentives • Education, labelling and information • Voluntary agreements	Instrumental discourse
2 Complexity-induced risk problems	*Risk-informed* (risk agent and causal chain)	→ Characterizing the available evidence • Expert consensus-seeking tools: – Delphi or consensus conferencing – Meta-analysis – Scenario construction, etc. • Results fed into routine operation	Epistemic discourse
	Robustness-focused (risk-absorbing system)	→ Improving buffer capacity of risk target through: • Additional safety factors • Redundancy and diversity in designing safety devices • Improving coping capacity • Establishing high-reliability organizations	
3 Uncertainty-induced risk problems	*Precaution-based* (risk agent)	→ Using hazard characteristics such as persistence and ubiquity as proxies for risk estimates Tools include: • Containment • ALARA (as low as reasonably achievable) and ALARP (as low as reasonably practicable) • BACT (best available control technology), etc.	Reflective discourse
	Resilience-focused (risk-absorbing system)	→ Improving capability to cope with surprises • Diversity of means to accomplish desired benefits • Avoiding high vulnerability • Allowing for flexible responses • Preparedness for adaptation	
4 Ambiguity-induced risk problems	*Discourse-based*	→ Application of conflict-resolution methods for reaching consensus or tolerance for risk evaluation results and management option selection • Integration of stakeholder involvement in reaching closure • Emphasis on communication and social discourse	Participatory discourse

Source: adapted from IRGC, 2005, p47

Table 3: Risk characteristics and their implications for risk management

2.1.8 Risk Evaluation Criteria

According to Renn (2008) nine criteria are chosen in Table 4 to represent most of the experts' and public concerns as the result of a long exercise of deliberation and investigations:

Criteria	Description
Extent of damage	Adverse effects in natural units, such as fatalities, injuries, production losses, etc.
Probability of occurrence	Estimate for the relative frequency of a discrete or continuous loss function
Incertitude	Overall indicator for different uncertainty components
Ubiquity	Defines the geographic dispersion of potential damages (intra-generational justice)
Persistency	Defines the temporal extension of potential damage (intergenerational justice)
Reversibility	Describes the possibility of restoring the situation to the state before the damage occurred (possible restoration – e.g. reforestation and cleaning of water)
Delay effect	Characterizes a long time of latency between the initial event and the actual impact of damage; the time of latency could be of physical, chemical or biological nature
Violation of equity	Describes the discrepancy between those who enjoy the benefits and those who bear the risks
Potential of mobilization	Is understood as a violation of individual, social or cultural interests and values, generating social conflicts and psychological reactions by individuals or groups who feel affected by the risk consequences

Source: adapted from WBGU, 2000, p56

Table 4: Risk characteristics and their implications for risk management

In reality, some criteria are tightly coupled and other combinations are theoretically possible; but there are no, or only a few, empirical examples (Renn, 2008, p.160-162).

2.1.9 Risk Classification based on Risk Characteristic

Table 5, lists six risk classes in tabular form, describes their main characteristics and provides examples for each type. This classification leads to six genuine risk classes that were given names from Greek mythology. The classification is the first step in evaluating the tolerability or acceptability of the risks by locating each risk within the traffic light model and is later used for designing appropriate management strategies (Renn, 2008, p.164-165).

Risk class	Probability	Extent of damage	Other criteria	Typical examples[6]
Damocles	Low	High		Nuclear energy, dams, large-scale chemical facilities
Cyclops	Indecisive	High		Nuclear early warning systems, earthquakes, volcanic eruptions, new infectious diseases
Pythia	Large uncertainty intervals	Potentially high		Greenhouse gas effect on extreme weather events, BSE, some GMOs, some applications of nanotechnology
Pandora	Unknown	Potentially high	High persistence	POPs, endocrine disruptors
Cassandra	High	High	Long delay	Anthropogenic climate change, destabilization of terrestrial ecosystems, threat to biodiversity
Medusa	Low	Low	High mobilization	Electromagnetic fields

Source: adapted from WBGU, 2000, p62

Table 5: Overview of the risk classes, their criteria, and typical representatives

Each risk class is indicative of a different pattern of complexity, uncertainty and ambiguity. Table 6 provides a simple overview of the six classes in relation to the three risk characteristics (Renn, 2008, p.165).

Characteristics	Explanation	Risk classes
Complexity	Multifaceted web of causal relationships where many intervening factors interact to affect the outcome of an event or an activity	• Sword of Damocles • Cyclops
Uncertainty	Lack of reliability or confidence in the postulated cause–effect relationships	• Pythia • Pandora's box
Ambiguity	Conflicting views about the interpretation of a risk and its tolerability	• Cassandra • Medusa

Source: Ortwin Renn

Table 6: Overview of different degrees of incertitude with regard to the main criteria and the risk classes

According to WBGU (2000), the essential aim of the risk classification is to locate risks in one of the three spaces of the traffic light diagram in order to assess its tolerability or acceptability. In addition, this classification helps to derive effective and feasible strategies, regulations and measures for risk reduction. The characterization provides a knowledge base so that risk managers can better select specific political strategies and measures that correspond to each risk class. To do this effectively, we propose a decision tree as the following diagram (Figure 2), in which five central questions have to be answered (Renn, 2008, p.166)

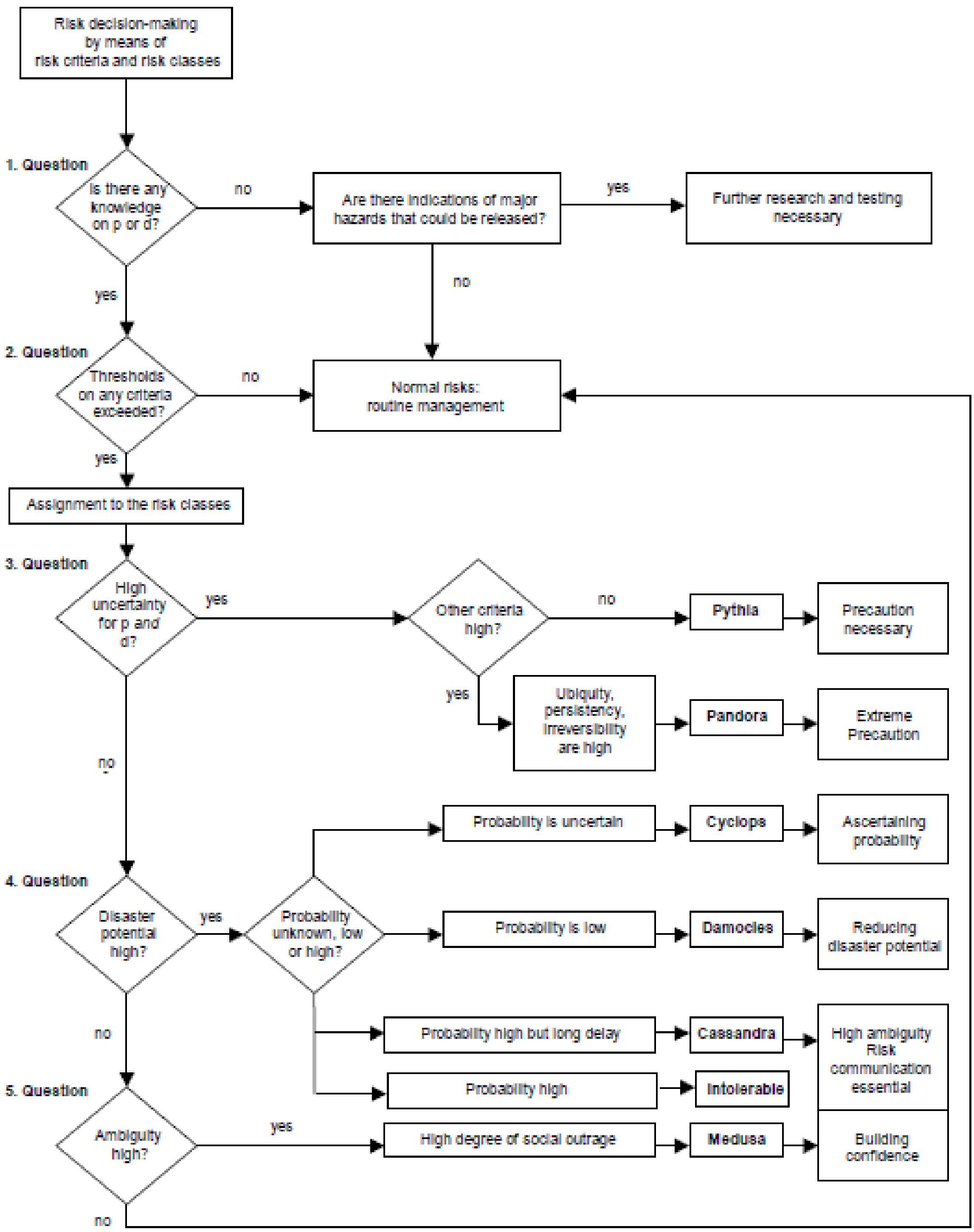

Figure 2: Decision tree for evaluating and classifying risks (Source: adapted from WBGU, 2000, p.7 and Klinke and Renn, 2002)

2.1.10 Addressing Risk/Benefit Analysis and Management

Risk management refers to all activities used to address risk, such as avoiding, reducing, sharing, and accepting risk. Risk assessments and cost-benefit types of analyses are examples of methods used to support risk management (Aven & Thekdi, 2022, p.201).

According to Aven and Thekdi (2022, p. 207): "Risk assessments and other types of analyses provide input to the process of obtaining the balance between development and protection, more specifically in relation to what option to select, the acceptance of activities and systems and so on. Aiming at such a balance means that we do not talk about risk in isolation. We have to look at what the alternatives are: the costs, benefits and risks of each, and find the overall best one. The risk associated with the alternative selected is by definition acceptable. If you consider two investment strategies, 1 or 2, and choose 1, it means that you accept the risk related to 1".

If input variables to decision-making can be properly defined and affirmed, risk characterization and evaluation can be done on the basis of risk–benefit balancing and normative standard-setting (risk-informed regulation) (Renn, 2008, p.178).

Research suggests an interesting relationship between perceived benefits and perceived risks for various hazards. Generally, the higher the perceived benefit, the lower the perceived risk, and vice versa. This can be observed in how people view smoking, considered high-risk with limited benefits, and antibiotics, seen as highly beneficial with minimal risks. This inverse relationship makes sense because we are more likely to accept risks when the benefits are significant (Aven & Thekdi, 2022, p.136).

Among the formal balancing procedures that serve as tools in the balancing process, risk–risk comparisons (r–r comparisons), cost-effectiveness procedures and cost–benefit analyses are the most suited instruments to perform the necessary balance. All three formal instruments can be of assistance in weighing pros and cons under the condition that there is little complexity, uncertainty and ambiguity (Renn, 2008, p.190).

Process of comparing the result of risk analysis against risk (and often benefit) criteria to determine the significance and acceptability of the risk is defined as Risk Evaluation (SRA, 2018, p.8).

Risk-benefit analysis is a technique which may be employed to assess the costs and benefits of a given activity, which involves risk. Risk assessment includes both the probabilities of various outcomes and the consequences of such outcomes expressed in dollar terms. Benefit assessments measure the benefits to the individual and society from the given activity (Dardis et al, 1983).

Benefit–risk models are useful tools for analysing potential benefits and risks associated with an intervention, product, or behaviour (Brass et al, 2011).

As per Brass et al (2011), probabilistic benefit–risk models were originally developed for the nuclear power and space sectors in the 1950s and 1960s.

Risk-Benefit analysis serves as a basis for comparing products since it includes both the costs and benefits of a consumption activity. In contrast, hazard analysis ignores the need for and the utility of the product to the consumer (Dardis et al, 1983).

Risk, cost, and benefit analysis can offer transparent ways to assemble and integrate relevant evidence to support complex decision-making. All forms of analysis have the same logic: Decompose complex systems into manageable components and then calculate how they might perform together (Fischhoff, 2015).

Risk-benefit analysis provides insight concerning the level of risk to which consumers are exposed. The issue of prevailing risk is of particular importance since a society that is not risk-free must decide what level of risk requires intervention. If there is no basis for determining when intervention is necessary then risk reduction activities may be ineffective, i.e., we may concentrate on low risk areas and ignore high risk areas (Dardis et al, 1983).

A cost-benefit analysis computes the expected net present value of a project or measure. Following this approach, all benefits and costs of the project are transformed to a common scale, typically money. If this value is positive, the project is recommended (Aven & Thekdi, 2022, p.232).

Risk, cost, and benefit analysis reflect a strategy of bounded rationality. Rather than attempting to address all aspects of a complex decision, such analyses “bound” it, in the sense of ignoring enough of its elements to be able treat those that remain “rationally.” Typically, that means estimating the expected effect of each decision option by multiplying the size of possible outcomes by their probability of occurring should the option be chosen (Fischhoff, 2015).

The EFSA (European Food Safety Authority) Scientific Colloquium 2006 concluded that a risk-benefit analysis should mirror the approach agreed upon for risk analysis. This implies that risk-benefit analysis includes a risk-benefit assessment, risk-benefit management, and risk-benefit communication. Here, the risk-benefit assessment is the scientific process where the potential adverse health effects are weighed against the potential beneficial health effects. The purpose of risk-benefit assessment is to offer scientific decision support to the risk-benefit manager. In this reference, the steps in risk-benefit assessment have been shown on Figure 3 (Hoekstra et al, 2023).

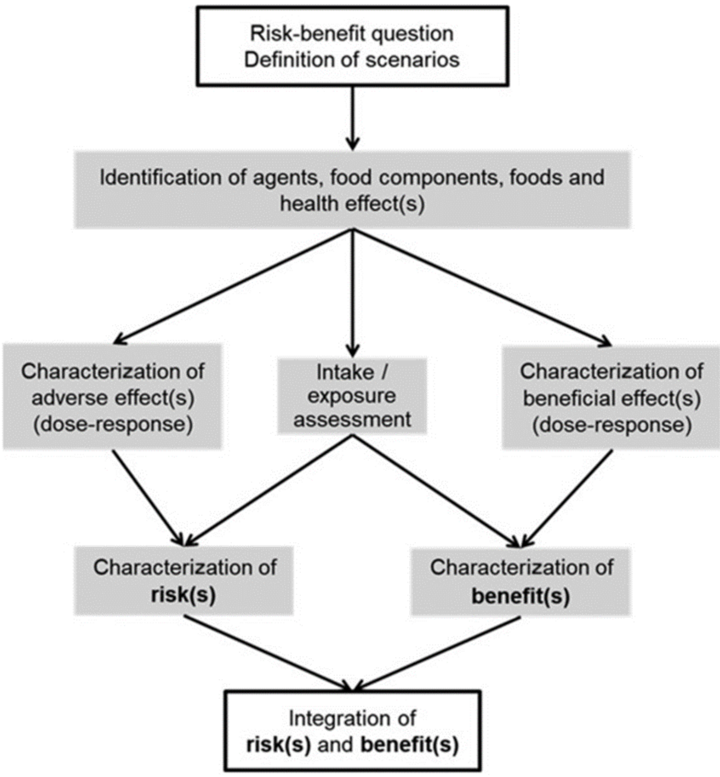

Figure 3: Steps in risk-benefit assessment

Interest in risk-benefit methodology as a decision-tool for evaluating risks with respect to public health and safety was evidenced in two conferences which were held in 1971 organized by the Committee on Public Engineering Policy, National

Academy of Engineering (Discussed Topics: data requirements for decision-making, the process of risk-benefit analysis and the problems of implementing good analyses) and in 1975 as part of a National Science Foundation funded study at UCLA (Discussed Topic: Risk assessment) (Dardis et al, 1983).

2.1.11 Risk-Benefit Analysis Methodologies

In the paper from Shahrul et al (2014), the authors systematically collected, appraised, and classified available benefit–risk methodologies to facilitate and inform their future use. They identified 49 methodologies (Table 7), critically appraised and classified them into four categories: frameworks, metrics, estimation techniques and utility survey techniques.

Methodology	Description	Methodology	Description
AE-NNT[55]	Adverse event adjusted number needed to treat	MAR[56]	Maximum acceptable risk
ASF[57,58]	Ashby and Smith framework	MCDA[49,59,60]	Multicriteria decision analysis
BLRA[61]	Benefit-less–risk analysis	MCE[62,63]	Minimum clinical efficacy
Beckmann[49,64]	Beckmann model (aka evidence based-model)	MDP[50,65]	Markov decision process
BRAFO[39]	Benefit–risk analysis for foods	MTC[3,4,66]	Mixed treatment comparison
BRAT[53,67]	Benefit–risk action team	NCB[68]	Net clinical benefit
BRR[16,69,70]	Benefit–risk ratio	NEAR[12,71]	Net efficacy adjusted for risk
CA[72,73]	Conjoint analysis	NNH[62,74]	Number needed to harm
CDS[2,75,76]	Cross-design synthesis	NNT[62,74]	Number needed to treat
CMR CASS[77]	CMR Health Canada, Australia's Therapeutic Goods Administration, SwissMedic and Singapore Health Science Authority	OMERACT 3 × 3[78]	Outcome measures in rheumatology 3 × 3
COBRA[54]	Consortium on benefit–risk assessment	Principle of 3's[49,79]	Principle of threes
CPM[1,80,81]	Confidence profile method	PrOACT-URL[82,83]	Problem, objectives, alternatives, consequences, trade-offs, uncertainty risk, and linked decisions framework
CUI[27,84,85]	Clinical utility index	PSM[86,87]	Probabilistic simulation method
CV[88–90]	Contingent valuation	QALY[30,31]	Quality-adjusted life years
DAG[91–94]	Directed acyclic graphs	Q-TWiST[95,96]	Quality-adjusted time without symptoms and toxicity
DALY[31]	Disability-adjusted life years	RV-MCE[62,63]	Relative value-adjusted minimum clinical efficacy
DCE[97–99]	Discrete choice experiment	RV-NNH[100]	Relative value-adjusted number needed to (treat to) harm
Decision tree[82,101,102]	Decision tree	SABRE[54]	Southeast Asia benefit–risk evaluation
DI[27,84,85]	desirability index	SBRAM[52]	Sarac's benefit–risk assessment
FDA BRF[103,104]	FDA benefit–risk framework	SMAA[105–107]	Stochastic multicriteria acceptability analysis
GBR[16,108]	Global benefit–risk	SPM[97]	Stated preference method
HALE[30,31]	Health-adjusted life years	TURBO[5,49]	Transparent uniform risk–benefit overview
Impact numbers[109–112]	Impact numbers	UMBRA[54]	Unified methodologies for benefit–risk assessment
INHB[10,113–115]	Incremental net health benefit	UT-NNT[116]	Utility-adjusted and time-adjusted number needed to treat
ITC[3,4,66]	Indirect treatment comparison		

Pharmacoepidemiology and Drug Safety, 2014; **23**: 667–678
DOI: 10.1002/pds

Table 7: List of risk- benefit methodologies

Methodologies are classified into categories based on four main focuses in Figure 4: (a) fundamental principles of the benefit–risk methodology; (b) features of the methodology; (c) whether there are any existing visual representations associated with the methodology; and (d) the assessability and accessibility of the methodology (Shahrul et al, 2014).

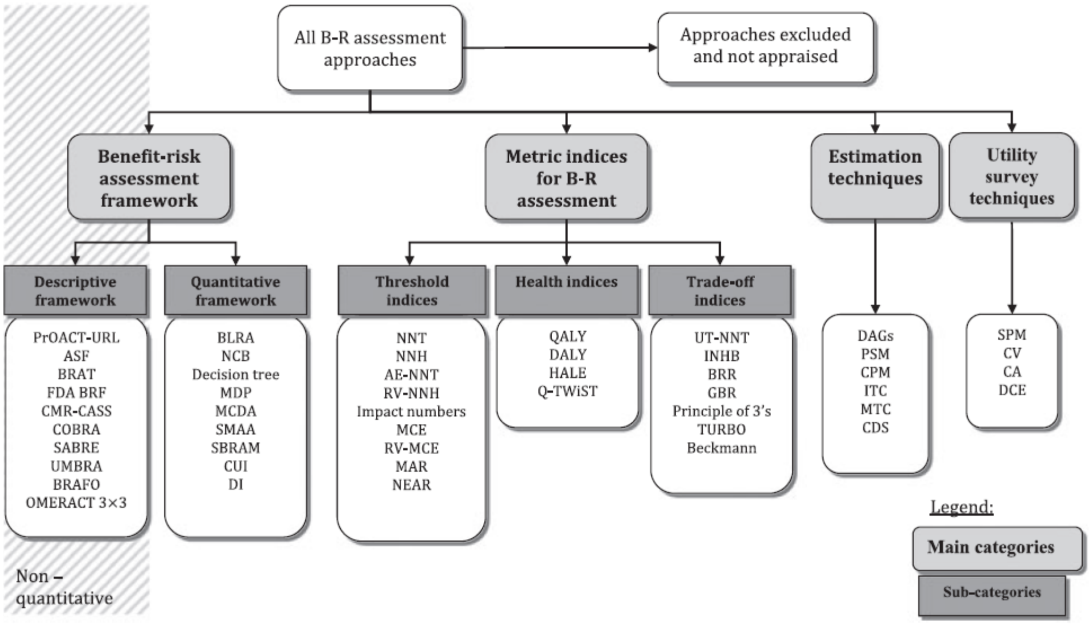

Figure 4: Classification of identified risk- benefit assessment methodologies

A comparative overview of the quantitative methodologies is provided by authors as Table 8. Descriptive frameworks are not described because their features differ from those of quantitative methods (Shahrul et al, 2014).

	Methodology	Discriminative scoring*	Level of complexity†	Number of options‡	Evidence data§	Perspective for stakeholders¶
Quantitative frameworks	NCB	High	Complex	>2	Population	Pharmaceutical companies, healthcare providers and regulatory agencies
	BLRA	High	Medium	>2	Individual	
	Decision tree	N/A	Complex	>2	Population or individual	
	MCDA	High	Complex	>2	Population or individual	
	SMAA	High	Complex	>2	Population or individual	
	CUI/DI	N/A	Complex	>2	Individual	
	MDP	N/A	Complex	>2	Population or individual	
	SBRAM	Low	Complex	≤ 2	Population	Pharmaceutical companies
Metrics	NNT and NNH	N/A	Simple	≤ 2	Population	Patients, healthcare providers and pharmaceutical companies
	AE-NNT	N/A	Simple	≤ 2	Individual	
	RV-NNH	N/A	Medium	≤ 2	Individual	
	Impact numbers	N/A	Simple	≤ 2	Population	Healthcare providers and pharmaceutical companies
	MCE	N/A	Simple	≤ 2	Population	
	RV-MCE	N/A	Medium	≤ 2	Individual	Patients, healthcare providers and pharmaceutical companies
	MAR	High	Medium	≤ 2	Individual	
	NEAR	N/A	Medium	≤ 2	Population	
	QALY	High	Medium	>2	Individual	Patients, healthcare providers, pharmaceutical companies and regulatory agencies
	DALY	High	Medium	>2	Individual and population	
	HALE	High	Medium	>2	Individual	
	Q-TWiST	High	Medium-complex	>2	Individual	Healthcare providers and regulatory authorities
	UT-NNT	N/A	Medium	≤ 2	Population	Patients, physicians and healthcare providers
	INHB	High	Medium	≤ 2	Population or individual	Patients, physicians, healthcare providers, pharmaceutical companies and regulatory agencies
	BRR	N/A	Simple	≤ 2	Population	Patients, physicians, healthcare providers and pharmaceutical companies
	GBR	Low	Medium	>2	Individual	
	Principle of threes	Low	Simple	>2	Population	Patients, physicians and healthcare providers
	TURBO	Medium	Simple	>2	Population	
	Beckmann	Undefined	Medium	>2	Population	
Estimation techniques	DAGs	N/A	Medium	>2	Population or individual	Pharmaceutical companies, healthcare providers and regulatory agencies
	PSM	N/A	Complex	>2	Population or individual	
	MDP	N/A	Complex	>2	Population or individual	
	CPM	N/A	Complex	>2	Population or individual	
	ITC and MTC	N/A	Complex	>2	Population or individual	
	CDS	N/A	Complex	>2	Population or individual	
Utility survey techniques	SPM	High	Medium	>2	Individual	Patients, physicians, healthcare providers, pharmaceutical companies and regulatory agencies
	CV	High	Medium	>2	Individual	
	CA	High	Complex	>2	Individual	
	DCE	High	Complex	>2	Individual	

NCB, net clinical benefit; BLRA, benefit-less–risk analysis; MCDA, multicriteria decision analysis; SMAA, stochastic multicriteria acceptability analysis; CUI/DI, clinical utility index/desirability index; MDP, Markov decision process; SBRAM, Sarac's benefit–risk assessment; NNT, number needed to treat; NNH, number needed to harm; AE-NNT, adverse event adjusted number needed to treat; RV-NNH, relative value-adjusted number needed to (treat to) harm; RV-MCE, relative value-adjusted minimum clinical efficacy; MAR, maximum acceptable risk; NEAR, net efficacy adjusted for risk; QALY, quality-adjusted life year; DALY, disability-adjusted life years; HALE, health-adjusted life years; Q-TWiST, quality-adjusted time without symptoms and toxicity; UT-NNT, utility-adjusted and time-adjusted number needed to treat; INHB, incremental net health benefit; BRR, benefit–risk ratio; GBR, global benefit–risk; TURBO, transparent uniform risk–benefit overview; DAG, directed acyclic graphs; PSM, probabilistic simulation method; CPM, confidence profile method; ITC, indirect treatment comparison; MTC, mixed treatment comparison; CDS, cross-design synthesis; SPM, stated preference method; CV, contingent valuation; CA, conjoint analysis; DCE, discrete choice experiment.

*Discriminative scoring describes the number of different levels to distinguish the values (performance, preference, etc.) associated with the consequences of each option employed by the scoring technique of a method: low (<5 levels), medium (≤5 levels <10), high (≥10 or on continuous scale) and N/A (method does not involve scoring).

†Level of complexity describes the technical difficulty in applying and/or understanding a method: simple (low technical difficulty that does not require medical/statistical expertise and does not require specialist software to implement), medium (mediocre technical difficulty that may need some but not extensive medical/statistical expertise and may require specialist software to implement) and complex (high technical difficulty that requires extensive medical/statistical expertise and may require specialist software to implement).

‡Number of options is the number of treatment options that can be compared simultaneously within a method. Typically, a method assesses ≤2 options, but it is not sufficient when there are multiple alternative treatments.

§Evidence data describes whether a method requires individual-level data or could be implemented using population summary data.

¶Perspective for stakeholders suggests the type of stakeholders, to whom a method may be of interest and/or suitable.

Table 8: Quantitative methodologies overview

2.2 Addressing Energy Transition

Since long ago, energy has played an important role in the development of human life. Many political and economic issues of countries are affected by energy and its availability. Despite the irreplaceable influence of fossil fuel on the development of current societies, due to its destructive effects on the environment and health, governments are forced to find an alternative to fossil fuel. They are conducting this aim through international meetings and creating joint agreements to achieve environmentally friendly solutions.

According to works by Baloch et al (2021) and Bashir (2022), the primary issue in the energy industry is environmental impact of fossil fuel use. It is crucial to mitigate this impact without hindering economic growth by eliminating harmful externalities. There may be a need for an energy shift in these circumstances in the form of energy transition which is crucial for restructuring energy consumption to achieve zero-carbon targets and maintain environmental sustainability in energy nexus (Aslam et al, 2024).

Additionally, the paper by Dong et al (2018), implies that the switch to renewable energy sources can encourage environmentally friendly development, reduce pollution, and ease ecosystem stress (Aslam et al, 2024). With refer to Bhattacharya et al (2017) and Dogan & Seker (2016), utilizing RE (Renewable Energy) is ultimately better for the environment. Utilizing renewable energy offers multiple benefits, including reduced dependence on non-renewable energy (NRE) markets, the opportunity for energy diversification, and mitigating the effects of climatic changes. To stop environmental deterioration, incentives, and opportunities for investing in clean energy should be made available (Aslam et al, 2024).

As per Moriarty and Honnery (2016) a key component of RE is energy protection and supply reliability. Fossil fuels contribute more to the world's energy consumption than RE sources, but they eventually run out of fuel. As a result, renewable energy sources are viewed as a long-term substitute for fossil fuel prices in terms of sustainability (Aslam et al, 2024).

Pryor and Barthelmie (2010) pointed that renewable energy does have some disadvantages, though, as it is more vulnerable to weather-related damage than non-renewable energy sources (Aslam et al, 2024). With refer to Supersberger and Führer (2011) and according to the work by Vaona (2016), energy diversification has been found to be essential for assuring energy supply security. RE boosts the level of securing energy by differentiating energy sources. One of the absolute necessities for guaranteeing energy supply and dependence. Shifting the usage of NRE to RE significantly reduces reliance on energy imports (Aslam et al, 2024).

According to Moriarty and Honnery (2016), RE is an important alternative to fossil fuels regarding long-term price stability and affordability of energy. Financial development significantly decreases energy security risk because financial development initiates technological innovation that initiates energy efficiency and energy use with less environmental burden and energy prices stability. At micro level, financial development increases energy affordability to use modern and clean energy at reasonable price and ensures energy security (Aslam et al, 2024).

2.3 Risk/Benefit of Energy Options for the Transition

2.3.1 The Importance of Looking at the Risk/Benefit of Energy Options for the Transition

Examining the risks and benefits of various energy options is essential for guiding the energy transition, ensuring decisions are well-informed and balanced. Policymakers, industry leaders, and stakeholders need comprehensive data to develop effective policies that maximize benefits while minimizing adverse impacts. This approach ensures an efficient, cost-effective, and socially aligned energy transition. Additionally, thorough risk-benefit analyses can provide stakeholders with a nuanced understanding of economic, environmental, and social implications of energy transition options.

Furthermore, detailed analyses can optimize resource allocation by identifying the most viable and beneficial energy options, thus accelerating the transition by focusing investments and efforts where they will have the greatest positive impact.

Understanding potential risks in detail allows for the development of strategies to mitigate adverse effects, ensuring the energy transition does not lead to unforeseen detrimental consequences. Comprehensive risk-benefit analyses also support long-term sustainability goals, such as reducing carbon emissions, preserving biodiversity, and promoting social equity. Moreover, these analyses help countries comply with international commitments like the Paris Agreement, demonstrating leadership and commitment to global climate goals. Therefore, examining the risks and benefits of energy options is indispensable for achieving a sustainable and resilient energy future.

2.3.2 Looking at System thinking, Risk/ Benefit analysis and their Application in Energy Transition

Based on ISO (2018), risk changes, often quickly, and a dynamic risk management approach is essential to be able to anticipate, detect, acknowledge and respond to these changes in an appropriate and timely manner (Aven & Thekdi, 2022, p.209).

Therefore, systems thinking can be considered as the whole picture, focusing on how individual components of a system interact and influence each other (Langdalen et al, 2020).

The idea of systems thinking is frequently referred to in accident analysis, organizational theories and quality discourse (Aven & Thekdi, 2022, p.209).

Langdalen et al (2020) provides some illustrating examples of the importance of systems thinking. A key point highlighted is that focusing on safety measures in isolation can prevent all relevant costs and benefits associated with a particular measure from being identified. In other words, to evaluate the effects of a safety measure, it is not sufficient to consider the measure in isolation (Langdalen et al, 2020)

As Abrahamsen et al (2018) pointed put, system thinking is required, as resources are limited– spending resources on some safety measures may imply reduced resources for other safety measures (Aven & Thekdi, 2022, p.209).

On the other hand, in society, there is a continuous ‘battle’ between development on the one side and protection on the other. This battle is rooted in differences in values and priorities but also in scientific and analytical argumentations. For example, public administration is strongly guided by the use of cost-benefit type of analysis (CBA), which means that risk and uncertainty considerations are given little attention beyond expected values. Hence the creating concern is highlighted more than protection. Following a cost-benefit type of analysis, nuclear industry in a country would normally be "justified" (Aven & Thekdi, 2022, p.221).

From all the above-mentioned points, as the case of energy transitions has different aspects to consider, there is a need to see it as a system which required a system view and risk/ benefit analysis should be conducted on the whole system to be more comprehensive.

2.3.3 Some of risk/ benefit examples regarding energy transition

Up to now there are several examples of different countries experience's on the subject of energy transition as bellow:

Based on Ethik-Kommission (2011), Germany has decided to phase out its nuclear power plants by the end of 2022 which this decision was made following the 2011 Fukushima nuclear disaster (Aven & Renn, 2018). There are risks related to both potential nuclear accidents and nuclear waste. The risks are not considered low enough to be acceptable and therefore judged unacceptable. Half of the German Ethics Commission, which paved the way for the German phase-out decision, argued that "Nuclear energy is not acceptable because of its catastrophic potential, independent of the probability of large accidents occurring and also independent of its economic benefit to society" (Aven & Renn, 2018).

According to Renn (2015) half of German Ethics Commission can be said to have given very strong weight to the cautionary principle. The other half argued using a cost-benefit type of reasoning: other means of electricity generation were feasible with almost the same benefit as nuclear power but with less risk (Aven & Renn, 2018).

Another experience regarding energy transition refers to Taiwan's case. The results showed that compared to the low electricity price in the southern part of Taiwan, it was still not economically feasible for a home owner-occupant to embrace renewable energy, even with a government subsidy (Hsu, 2008).

2.3.4 A comparison between TETs (Traditional Energy Technologies) vs. RETs (Renewable Energy Technologies)

According to a paper from HSU (2010), risk characteristics of TETs and RETs can be listed as Table 9:

	Input/ Cost components	**Output / Benefit and Externality**
RETs	1. More expensive initial capital investment compared to traditional fuels 2. Zero fuel price 3. Quantity of electric power generated fluctuates according to weather variations 4. Little maintenance and low operation fee across facility life cycle	1. Electricity power 2. Little GHG emission/GWP
TETs	1. Sunken cost of former capital investment 2. Fuel price with high escalation rate and volatility rate ***National/regional scale:*** 3. Uneven fuel distribution affecting energy security of the country 4. Global fuel potential exhausted	1. Electricity power 2. Large GHG emission/GWP

Table 9: Comparisons of risk characteristics of TETs and RTEs

Based on the primary comparison among renewable energy and traditional energy, the major differences between renewable and traditional energy include Risk and Externality. In terms of Externality, the negative externalities accompanying traditional electric power production process are always on a global scale (Hsu, 2010).

In terms of Risk, an examination of the effects of different risk properties regarding renewable and traditional energy technology reveals that RETs are always viewed as an intermittent energy source; as a result, the stochastic production quantity always involves variability. The risk of traditional energy technologies is mainly based on fuel price escalation and fluctuations along the whole life span (Hsu, 2010).

2.3.4.1 Variability of RETs

Sinden (2007) used UK empirical data to show that onshore wind speed correlations rapidly decrease as distance between wind farms increase; in other words, sites far apart exhibit very low correlation (Sinden, 2007). Thus, the variability of wind energy in combination with dispersed location will significantly lower the electric generation risk. As per IEA (2008) empirical data in Germany also showed high wind in the winter and more sun in the summer (Hsu, 2010). The inverse correlation of seasonal capacity factors (actual power output divided by maximum potential output) of wind and PV can be complementary via careful renewable planning; this showed that the variability of renewable issues can be transformed via management strategies, technical system integration, and planning processes (Hsu, 2010).

2.3.4.2 Fuel price risk

Market risk of the traditional energy production includes fuel price escalation and fluctuations. There are two kinds of approach that deal with market risk: national/regional policy level and project-based level. As we discussed in the previous section, national/regional policy uses the portfolio theory to determine the optimal level of RETs. At a project-based level, if we hope to combine the market and production uncertainty in the framework of the economic analysis of RETs, we will face the problem of computing energy-saving functions. How can the risky information on traditional energy technology be integrated into an energy-saving function? Some transformational method needs be developed in advance. By examining the risk properties within different energy technologies, we find the asymmetry risk between renewable and traditional energy. This will definitely affect the result of project-based economic analysis. These biases will hinder research results. For example, the fuel price risk in a traditional energy technology will result in higher risk-premium cost and cost transfer to the end user. Also, whenever analyzing the renewable technologies, this risk from the counter-side alternative energy cannot be assigned to an energy-saving function. Whenever the asymmetry risk is misallocated, biases will follow. Without proper treatments of the model specification, these asymmetry risk properties will affect the result of a project-based economic analysis; thus, biases will definitely hinder research results (Hsu, 2010).

3. Research Question and Research Methodology

3.1 Research Question

Since the 2016 Paris Agreement, the international desire to switch over to sustainable forms of energy resources has increased, leading to an all-time high level of debate on risks and benefits associated with different renewable energy options. Our research is focused on understanding this debate, related to wind energy in Norway, which is an interesting country for various reasons.

Norway is a specific and important case since it has been one of the leading countries regarding renewable energy for a long time, mostly based on intensive hydropower use. So, diversification of renewable energy portfolio in Norway can be important in meeting the country's and global climate targets, particularly under the Paris Agreement.

Besides, the geographical and climatic features of Norway enable the country to be a good place to develop wind energy. The nation has vast stretches of the coastline with very high wind speeds, which offer huge potential for efficient wind energy generation. By focusing on Norway, our research can offer insights that not only relate to the country itself but are also useful for other regions with similar conditions.

The energy from the wind is developing very fast all around the world as a great source of renewable energy, which can meaningfully contribute to energy transition. In Norway's context, discussions over wind energy development clarify the controversy among experts, policymakers, and the public. Such debate mostly seems to revolve around difficulties with wind energy—a subject full of issues to consider.

The period following the 2016 Paris Agreement has seen a heightened focus on transitioning to renewable energy sources, with significant advancements in technology, policy, and public awareness. Analyzing expert discussions during this period allows us to capture the most current and relevant considerations in the field of renewable energy transition.

In line with the above-mentioned explanation, the following research main question and Sub-questions have been considered in this thesis.

"What is the focus of expert discussion after the Paris Agreement (2016) on the risk and benefit of wind energy in Norway as a key energy source to achieve energy transition?"

To delve deeper into this overarching question, we have identified two sub-questions:

- **Have they considered more risk or benefit? Or have they looked at both at the same time?**

  This sub-question will try to look into expert emphasis on the discussion, whether it has been considerably focused on the risks, the benefits, or a balanced view of the two. Knowing this emphasis enables us to bring out the predominant attitudes and concerns towards wind energy in Norway.

- **What is the frequency of dealing with different categories of risks and benefits (consisting of political, economic, social, technical, legal and environmental (PESTLE)) among various English sources?**

This sub-question seeks to categorize and quantify the discussions around different types of risks and benefits. By analyzing the frequency of these categories, we can identify which aspects are most prominent in the discourse, providing a thorough understanding of the factors driving the conversation about wind energy in Norway.

By selecting Norway as our case study and focusing on wind energy post-Paris Agreement, our research aims to contribute valuable insights into the risks and benefits of renewable energy transition. This approach not only highlights the specific dynamics at play in Norway but also offers broader lessons for other countries navigating similar transitions.

3.2 Research Methodology

Research methodology is the backbone of any academic investigation, providing a systematic framework for conducting research, analyzing data, and drawing conclusions. The research methodology in this thesis outlines the steps taken to collect, filter, and analyze relevant literature (focusing on review articles) using a systematic review approach with the aid of bibliometric analysis.

The purpose of this methodology section is multifold. Firstly, it serves to establish the methodological rigor of our research by detailing the strategies employed to gather and interpret data. Secondly, it offers transparency by providing a clear and replicable process for future researchers interested in similar topics. Thirdly, it ensures the validity and reliability of our findings by outlining the systematic approach taken to analyze the literature.

In our thesis, this section serves as a critical link between the research question and the empirical data. By delineating our approach to identifying and analyzing relevant literature, we lay the groundwork for exploring the risks and benefits of wind energy in Norway within the context of energy transition post-2016. Through this methodology, we aim to uncover key insights, contribute to the existing body of knowledge, and inform policy and practice in the field of renewable energy and sustainability.

The specific steps undertaken in our research methodology to achieve these objectives have been introduced in the following.

3.2.1 Selection of Data Sources

3.2.1.1 Scopus as a source for selecting journals

Scopus was chosen as the primary database due to its extensive coverage of scholarly literature across various disciplines. Scopus is an abstract and citation database launched by the academic publisher Elsevier. Scopus indexes over 27,000 peer-reviewed journals from more than 7,000 publishers worldwide, making it one of the largest abstract and citation databases available (www.elsevier.com). This comprehensive coverage ensures that our search encompasses a wide range of relevant publications, providing a robust foundation for our research.

Furthermore, Scopus offers advanced search and filtering capabilities, allowing us to refine our search criteria to include only high-quality, peer-reviewed journals. This ensures that the articles we retrieve are reliable and authoritative sources of information. Figure 5 reveals an overview about the data source of Scopus.

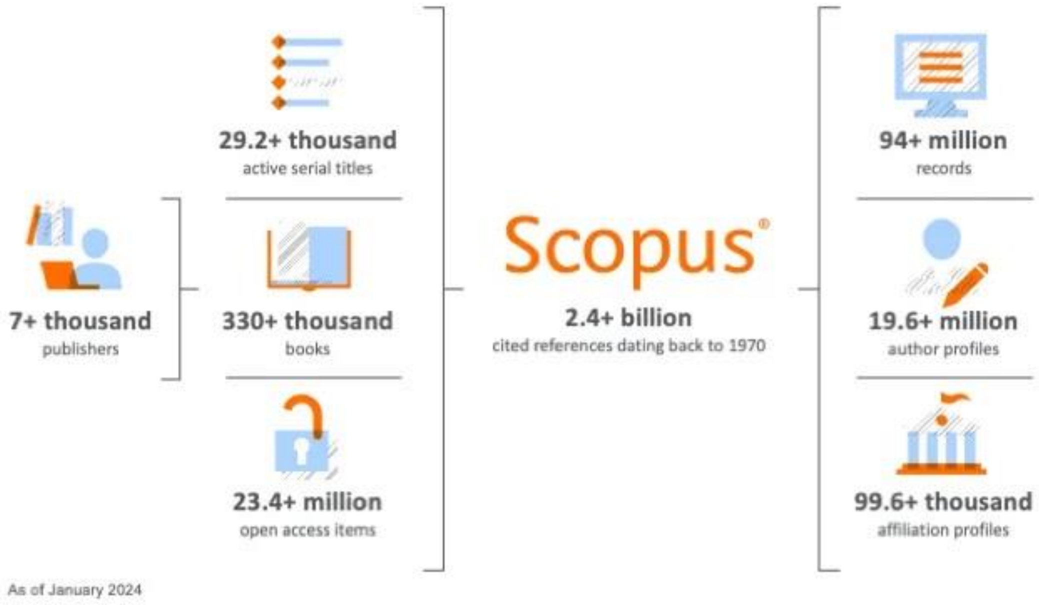

Figure 5: Scopus data source infographic view adapted (from https://www.elsevier.com)

3.2.1.2 Google Scholar as a source for selecting review articles

Google Scholar is a freely accessible web search engine that indexes the full text or metadata of scholarly literature across a wide array of publishing formats and disciplines. It includes peer-reviewed articles, theses, books, conference papers, preprints, abstracts, technical reports, and other scholarly literature. This extensive coverage makes it an invaluable resource for academic research.

We selected Google Scholar as a complementary platform to Scopus data source due to its broader search scope. Unlike traditional databases, Google Scholar indexes a wide variety of scholarly materials, ensuring comprehensive coverage of relevant sources. Its advanced search features allow for precise query customization, focusing on specific keywords and recent publications.

3.2.2 Data Collection

3.2.2.1 Data collection in Scopus data source

In the Scopus data source, we selected only journals over other sources such as book series, conference proceedings, and trade publications because journals undergo rigorous peer-review processes, ensuring high-quality and reliable research. They provide in-depth analyses and comprehensive coverage of relevant issues, making them ideal for our research purposes. Additionally, journals offer stability and enduring relevance in the academic community, unlike more transient sources.

By filtering journals to include only those in the first (Q1) and second (Q2) quartiles, we ensure that the selected articles are not only peer-reviewed but also of high quality and relevance to our research topic. Q1 and Q2 journals typically represent the most influential and reputable sources in their respective fields, making them suitable for capturing expert discussions regarding the research question.

In the Scopus platform, we chose the subject areas "Renewable Energy, Sustainability and the Environment" and "Safety, Risk, Reliability and Quality" for our thesis for the following reasons.

The subject area of 'Renewable Energy, Sustainability and the Environment' were chosen in Scopus data source because they directly align with the core focus of our thesis topic and research question. This area encompasses a wide range of topics related to renewable energy technologies, environmental impact assessments, and sustainable development practices. By focusing on this subject area, we ensure that our literature review captures the most relevant discussions on wind energy.

The selection of 'Safety, Risk, Reliability and Quality' is driven by our specific interest in the risks associated with wind energy in Norway. Articles in this field are expected to provide insights into risk assessment methodologies, safety standards, and reliability issues in different topics.

By combining these two subject areas, we cover a comprehensive spectrum of topics relevant to our research question. Total number of filtered journals in the mentioned two subject areas are 255 (156 journals for 'Renewable Energy, Sustainability and the Environment' and 99 journals for 'Safety, Risk, Reliability and Quality').

The following chart (Figure 6) provides an overall view about the number of journals found in this stage.

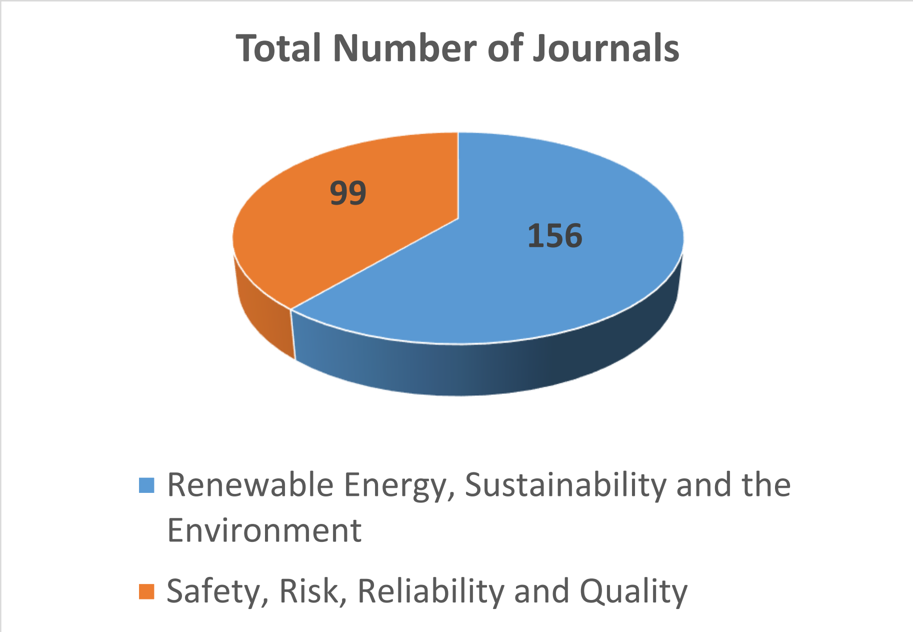

Figure 6: Number of Journals in two subject areas of 'Renewable Energy, Sustainability and the Environment' and 'Safety, Risk, Reliability and Quality'

3.2.2.2 Data collection in Google Scholar data source

3.2.2.2.1 Keyword selection

The following keywords were selected to limit the articles in the Google Scholar platform.

-"Risk" and "Benefit": These keywords are essential for capturing discussions related to the risks and benefits of wind energy. They help in identifying articles that discuss the potential impacts, both positive and negative, associated with wind energy projects.

-"Energy Transition": This keyword is crucial for focusing on the broader context of shifting from fossil fuels to renewable energy sources, with wind energy as a key component.

-"Norway": Including this keyword ensures that the articles are geographically relevant, focusing on the specific case of Norway's wind energy initiatives.

-"Wind Energy": This is another focus point of our research, and including this keyword ensures that the articles specifically address wind energy rather than other forms of renewable energy.

3.2.2.2.2 Selection of Publication Timeframe

The timeframe of (2016-2024) captures recent discussions following the Paris Agreement in 2016, which marked a significant global commitment to reducing carbon emissions and transitioning to renewable energy sources. Focusing on this period ensures that the literature reflects the most current developments, policies, and expert discussions in the field.

3.2.2.2.3 Selection of Review Articles

Limiting the search to review articles ensures a focus on synthesized insights and expert opinions rather than individual research findings. This approach helps in consolidating a wide range of studies into coherent narratives and comprehensive overviews, making it easier to identify key trends, debates, and expert consensus in the field.

We specifically selected 'Review Articles' for several reasons:

-Synthesis of Expert Opinions: Review articles comprehensively indicate existing literature, while synthesizing findings of several studies. These syntheses are of great assistance in spotting general trends, expert opinions, and consensus within the field. It is particularly useful in trying to know the broader implications of wind energy, which entails risks and benefits.

-Identification of Key Trends and Debates: By compiling and analyzing numerous individual studies, review articles highlight key trends and ongoing debates in the literature. This makes them valuable for our research, as they offer insights into the prevailing discussions and emerging issues related to wind energy in Norway.

-Comprehensive Coverage: Review articles tend to cover a wide range of topics within a specific field, providing a more holistic view compared to individual research studies. This comprehensive coverage ensures that we capture a full spectrum of perspectives and findings relevant to our research question.

3.2.2.2.4 Visual Representation of Data

The following visual schemes (Figure 7, Figure 8 and Figure 9) enhance the understanding and give an overall presentation of the status of data collection results.

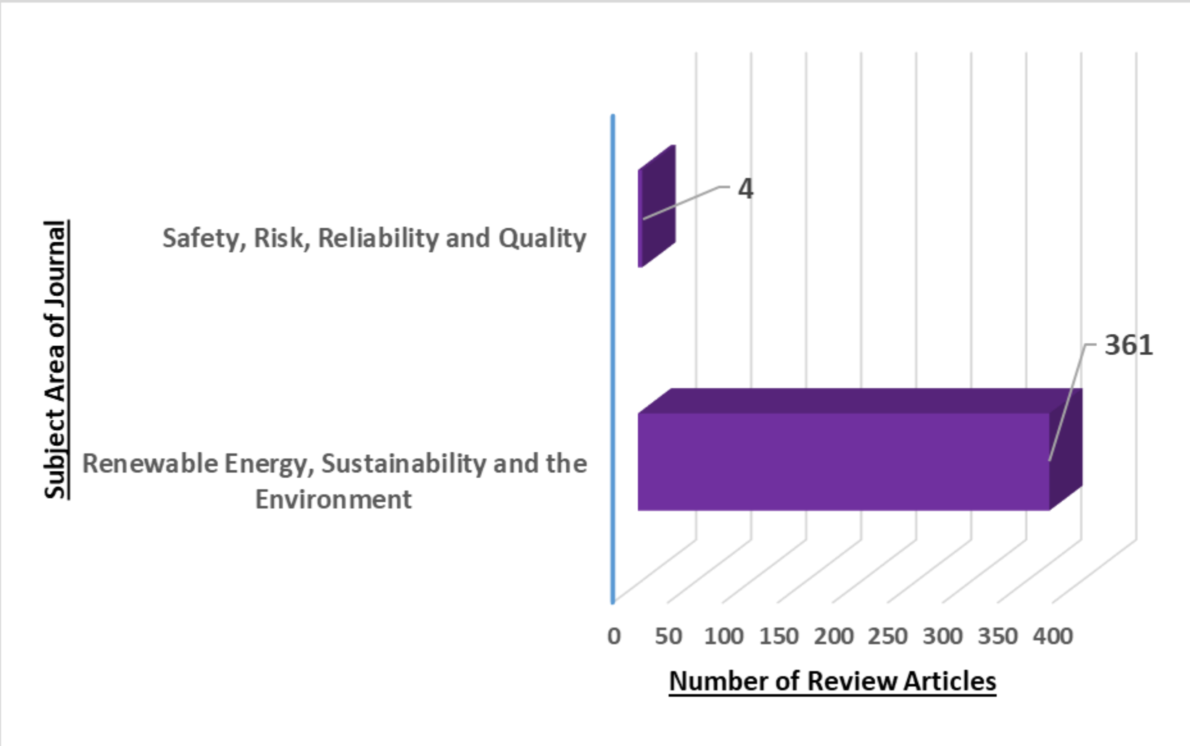

Figure 7: Number of Publications in two selected subject areas

Based on Figure 7, the most publications are in the subject area of 'Renewable Energy, Sustainability and the Environment'.

Figure 8 gives a comparison on the number of review articles in each journal for the subject area of 'Renewable Energy, Sustainability and the Environment'.

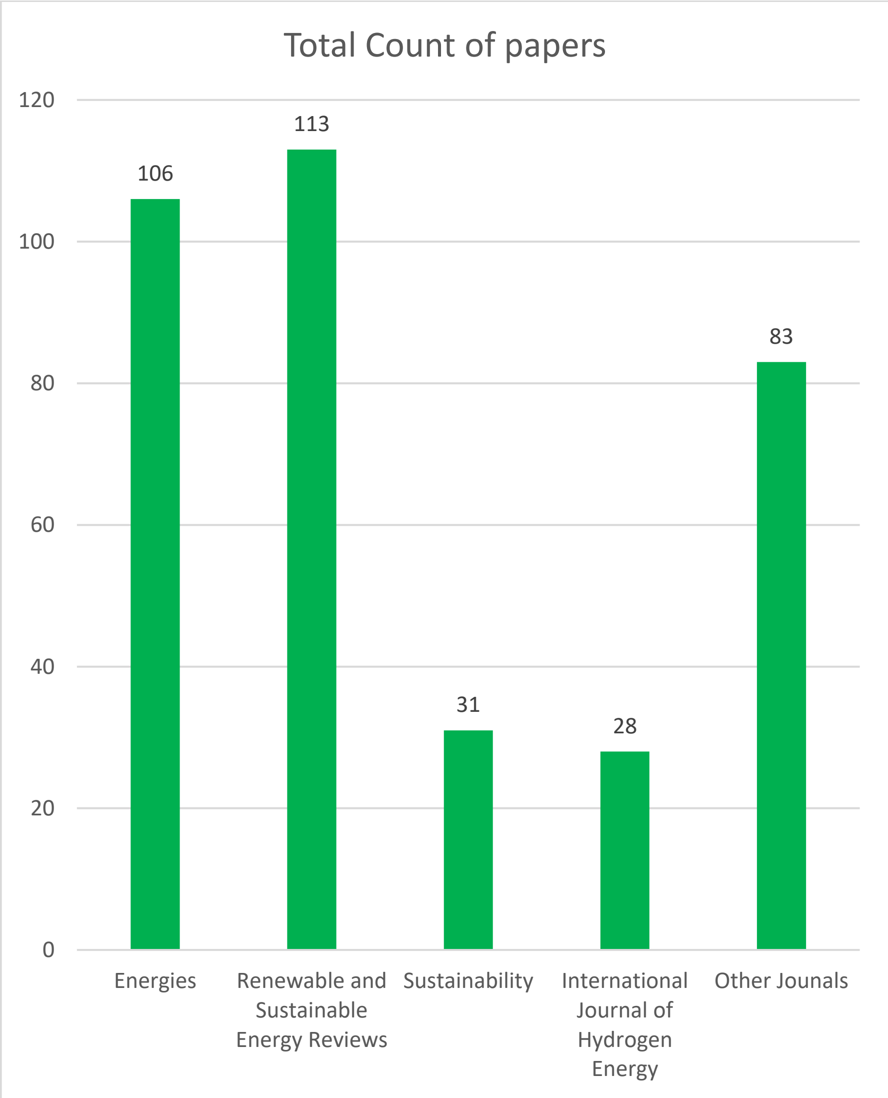

Figure 8: Comparison on the number of papers in each journal in the field of 'Renewable Energy, Sustainability and the Environment'

Figure 8, shows that the two journals' "Energies" and "Reviews of renewable and sustainable energies" include more than 60% of all the articles selected for study in this thesis.

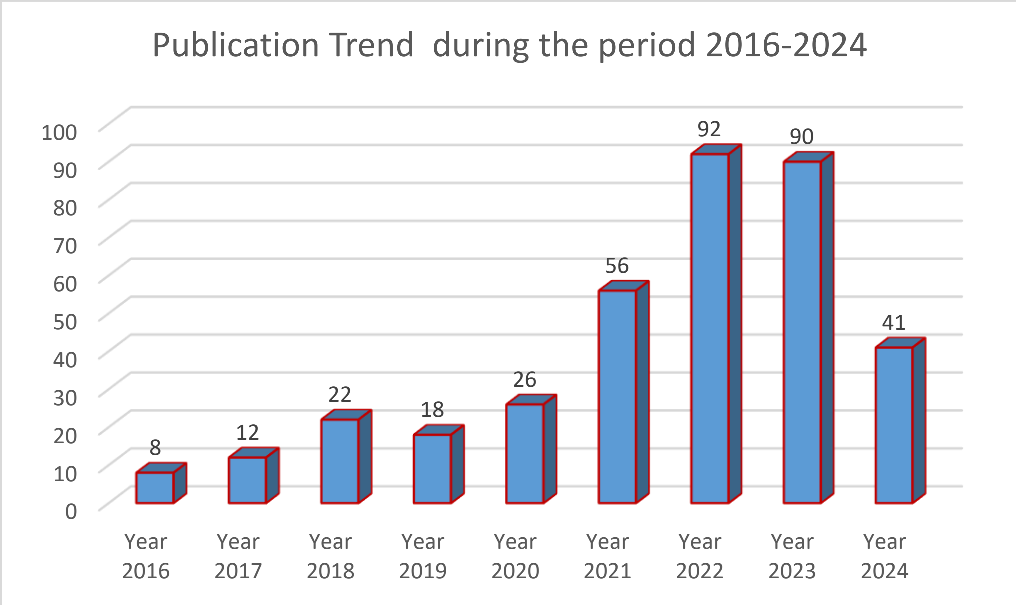

Figure 9: Publication trend during the period 2016-2024

Based on Figure 9, the number of published review articles found based on the key words and previous research methodologies shows a significant upward trend from 2016 to 2024, reflecting growing research interest in the topic. The initial years (2016-2019) saw a gradual increase in publications, starting with 8 articles in 2016 and reaching 22 articles in 2018, followed by a slight dip to 18 in 2019. The years 2020 and 2021 marked a notable surge, with articles increasing from 26 in 2020 to 56 in 2021. The peak publication years were 2022 and 2023, 92 and 90 articles respectively, indicating heightened scholarly activity and focus. Also, 2024 which has not finished yet shows 41 articles, still significantly higher than the initial years. This trend illustrates a robust increase in research activity post-Paris Agreement, peaking in the early 2020s. A line graph could effectively visualize this upward trend and subsequent fluctuation, underscoring the dynamic nature of academic interest in wind energy and sustainability.

4. Result

After the stage of the data collection, we compiled a comprehensive list of relevant review articles. The subsequent stage involved several key steps to systematically evaluate and categorize these articles. This section outlines the methodology employed in reviewing the collected data and the consequent results.

4.1 Review and Keyword Extraction

Initially, we conducted a thorough review of each article by reading the abstract and conclusion sections to extract pertinent information and insights related to our research question. We took important notes to capture our understanding of each article's content. Following this initial review, we identified and counted the occurrences of the selected keywords: "risk," "benefit," "energy transition," "Norway," and "wind energy." These keywords were registered in a database to facilitate systematic analysis.

This keyword analysis helped quantify the focus areas within each article, providing a basis for further categorization. Subsequently, we conducted an in-depth review of the articles with a high frequency of the mentioned keywords to update and refine our findings. We were particularly sensitive about the word "Norway" and "wind" energy, and even if these words were seen once in the text, we checked the relevant text carefully. This deeper examination ensured that we captured the most relevant and nuanced insights from the literature, allowing for a more comprehensive understanding of the expert discussions on the risks and benefits of wind energy in Norway.

The following diagram (Figure 10) shows an overall estimation of the average iteration of keywords in the reviewed articles.

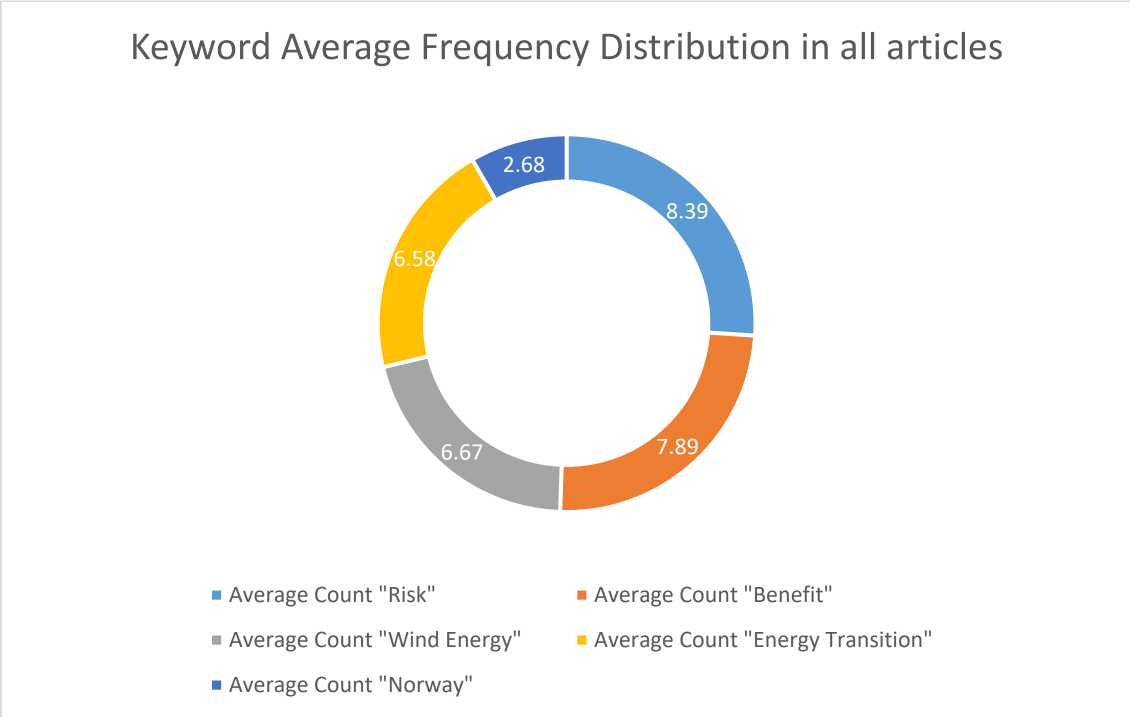

Figure 10: Keyword Average Frequency Distribution in all articles

The data reveals that "Risk" is the most frequently occurring keyword, with an average occurrence of 8.39 times per article. This is closely followed by "Benefit," with an average frequency of 7.89. "Wind Energy" and "Energy Transition" have similar occurrences, averaging 6.67 and 6.58 respectively. The keyword "Norway" appears less frequently, with an average of 2.68 occurrences per article. The higher frequencies of "Risk" and "Benefit" can indicate a strong focus on these aspects in the literature. Additionally, the relatively lower occurrence of "Norway" suggests that while the geographical context is essential, the discussions are heavily centered on the thematic elements of risk, benefit, wind energy, and energy transition.

In addition, Figure 11 shows the average frequency of selected keywords in articles from "Energies" and "Renewable and Sustainable Energy Reviews". "Renewable and Sustainable Energy Reviews" consistently has higher keyword frequencies, with "Risk" and "Benefit" being the most frequent, indicating a strong focus on these aspects. In comparison, "Energies" has lower frequencies, with "Benefit" and "Wind Energy" being the most common keywords. "Norway" appears least frequently in both journals.

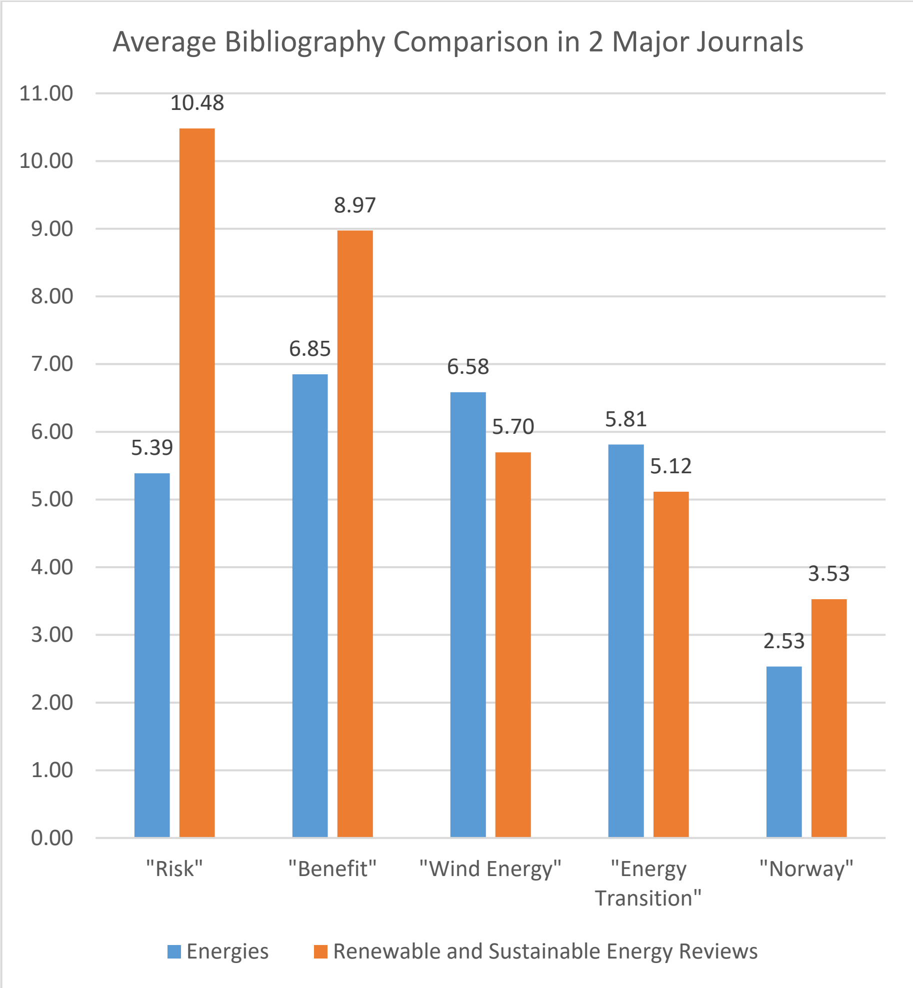

Figure 11: Average bibliography comparison in two major journals

4.2 Data Categorization

After extracting the keywords, we summarized the key findings from all found articles: [1-25, 27, 31-45, 47-75, 77-109, 111-131, 133-134, 137-181, 183-198, 200-233, 235-289, 291-309, 311-320, 322-353, 355-382]. This summary included the main conclusions, identified risks and benefits of wind energy, discussed incentives, obstacles, challenges, barriers, drivers and any notable trends or debates highlighted by the authors. This step ensured that we captured the essence of each article's contribution to the field and its relevance to our research objectives.

To systematically organize the literature, we expected to be able to categorize the articles into the following four groups based on their content and focus:

-Category 1: Articles directly addressing the risks or benefits of wind energy in Norway. These articles can provide detailed analyses of the potential risks and benefits of transition to wind energy in Norway. Category 1 was defined because it could directly answer the research question.

-Category 2: Articles discussing related topics other than risk and benefit such as incentives, obstacles, drivers, barriers, and challenges of wind energy in Norway. This category includes studies that explore policy measures, economic incentives, technical obstacles, and other contextual factors influencing transition to wind energy in Norway.

-Category 3: Articles dealing with renewable energy in general, including wind energy, but not specific to Norway. These articles offer broader insights into renewable energy technologies and related topics, while not exclusively focused on Norway, still provide valuable context for understanding wind energy's role in global energy transitions.

-Category 4: Articles not relevant to the scope of the thesis. These articles were excluded from further analysis as they did not directly pertain to our research question or provided limited value in addressing the specific focus of our study.

To facilitate a clear understanding of our findings, the diagram below (Figure 12) illustrates the number and the percentage of the reviewed articles in each category. This visual representation helps to quickly convey the distribution of research focus within the reviewed literature.

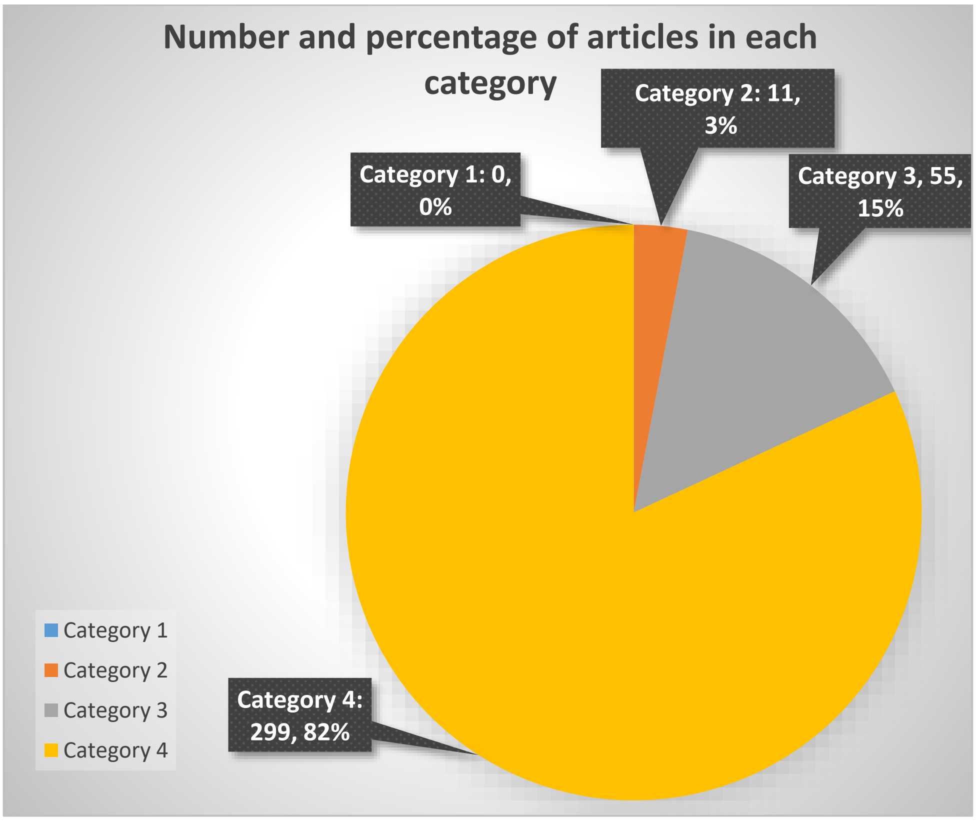

Figure 12: Distribution of Articles by Category

4.2.1 Findings for Category 1

Notably, there are zero articles in category 1. This finding indicates a potential gap in the literature regarding explicit discussions on the risks and benefits of wind energy specific to Norway. The implication of this gap is discussed in detail in the next chapter of the thesis.

The majority of articles, 299 in total, fall into category 4. These articles were deemed not pertinent to the research focus and thus were excluded from further analysis.

In the following, by examining the content and key themes identified in the reviewed articles, detailed findings are presented for the remaining categories (Categories 2 and 3).

4.2.2 Findings for Category 2

Among the 365 reviewed papers, we just found 11 papers [53, 73, 91, 94, 188, 201, 204, 265, 280, 325 & 343] referring to so called challenges, berries or drivers of the transition to wind energy in Norway. The key findings from this category are summarized in Table 10.

Topic Area	Driver/Barrier	Description	Reference
Political	Driver	Security of energy supply during winter through increased hydropower efficiency due to wind power.	[325]
	Barrier	Fluctuating government interest in offshore wind.	[343]
		High political focus on oil and gas.	[343]
Economic	Driver	Potential for economic benefits in rural areas through job creation and income generation.	[188]
		Local taxation benefits from wind farm development.	[73], [188]
		Reducing electricity imports during peak demand periods in winter.	[204]
	Barrier	Competition from cheap hydroelectric power.	[343]
Social	Driver	Public perception generally supportive of wind power.	[188]
	Barrier	Negative impacts on local communities' sense of place, identity and attachment to rural landscapes.	[188]
		Public concerns about biodiversity and wildlife impacts.	[188]
Technical	Driver	Technological advancements in offshore wind power, making it more efficient and feasible.	[343]
		Repowering of existing wind turbines can increase capacity without additional visual impact.	[91]
		Enhancing capacity margins and reducing the power outages in areas with limited grid capacity.	[325]
	Barrier	Technical limitations for offshore wind development in deep waters.	[343]
Legal & Regulatory	Driver	New European directive promoting energy communities, potentially empowering end-users and boosting renewable energy use.	[201]
	Barrier	Current Norwegian legal framework allowing land expropriation for wind farms, reducing landowner negotiation power.	[73]
Environmental	Barrier	Potential negative impacts of wind turbines on birdlife.	[53], [280]
		Opponents argue that Norway's existing renewable energy infrastructure makes wind power unneeded.	[188]

Table 10: Key findings for reviewed papers in Category 2

While Category 2 articles provided relevant context, an integrated discussion within each thematic area is presented below:

4.2.2.1 Political Drivers and Barriers

Several studies highlighted the potential of wind power to enhance Norway's energy security during winter when hydropower production is reduced (Söder et al, 2020). However, fluctuating political interest, continued prioritization of the oil and gas sector and existing decarbonized electricity were seen as barriers to offshore wind development (Van der Loos, 2021).

4.2.2.2 Economic Drivers and Barriers

From an economic perspective, wind energy was viewed as an opportunity for rural development through job creation, income generation, and local taxation benefits (Copena & Simón ,2018; Leiren et al, 2020). Moreover, integration of wind energy can decrease the need for electricity imports during high-demand winter periods (Ma et al, 2018). Nonetheless, the presence of cheap hydroelectric power and rebound in oil and gas prices were perceived as economic barriers to wind energy adoption (Van der Loos et al, 2021).

4.2.2.3 Social Drivers and Barriers

While public perception was reported to be supportive of wind power, concerns were raised about negative impacts on local communities' sense of place, identity, and attachment to rural landscapes (Leiren et al, 2020).

4.2.2.4 Environmental Barriers

Environmental issues such as potential threats to biodiversity and wildlife, beside negative impacts on fauna and flora have been perceived as barriers. In addition, some opponents arguing that Norway's existing renewable energy infrastructure renders wind power unnecessary (C. Gil-García et al, 2021; EL Kinani et al, 2023; Leiren et al, 2020; Rahman et al, 2022).

4.2.2.5 Technical Drivers and Barriers

Offshore oil and gas competencies, maritime expertise and industrial proximity were seen as drivers. Repowering of existing wind turbines was also viewed as an opportunity to increase capacity without additional visual impact (Doukas et al, 2022). However, rich offshore wind resources (but deep waters) and geographic proximity have been seen as both positive and negative influences on offshore wind system. in addition, other Norwegian studies have shown that wind power can increase the capacity margin and reduce the loss of load expectations in regions limited grid capacity (Söder et al, 2020).

4.2.2.6 Legal and Regulatory Drivers and Barriers

The new European directive promoting energy communities was perceived as a potential driver for boosting renewable energy use (López et al, 2024). Conversely, the current Norwegian legal framework, which allows land expropriation for wind farm development, was seen as a barrier as it reduces landowners' negotiation power (Copena & Simón ,2018).

4.2.3 Findings for Category 3

Among 55 papers in the category 3 [9, 11, 12, 16, 17, 20, 23, 25, 37, 38, 52, 66, 69, 71, 79, 96, 97, 104, 105, 118, 119, 124, 138, 140, 148, 153, 161-164, 181, 193, 195, 221, 244, 254, 271, 272, 278, 306, 313, 318, 323, 332, 336, 344-346, 348, 356, 368, 374, 375, 379 & 382], about 12 papers [17, 23, 38, 105, 153, 162, 163, 181, 244, 271, 368 & 382] are considered that they have major points regarding risk, benefit, challenges, barriers and drivers in a regional or global scale other than Norway. The key results from this category are summarized as Table 11:

Topic Area	Aspect	Description	Reference
Environmental	Benefit	Reduced environmental impacts compared to fossil fuels.	[23]
	Risk	Potential impacts on ecosystems, biodiversity, noise pollution, and landscape changes.	[17], [162], [163],[181]
	Advantage	Clean form of energy conversion.	[368]
	Drawback	Complexity and badness of the marine environment, the inefficiency and instability of power conversion and transmission	[368]
Economic	Benefit	Job creation in coastal regions and economic growth opportunities.	[181]
	Risk	Job displacement in fossil fuel sectors. Economic impacts on fossil fuel-dependent communities.	[23]
	Drawback	The high cost of system construction and O&M.	[368]
Social	Benefit	Improved quality of life for communities.	[23]
		Potential of lower public opposition for floating offshore wind farms due to their reduced environmental impact and minimal interference with other activities	[38]
	Risk	Visual annoyance and public acceptance challenges.	[162],[163]
	Barrier	Social acceptance of wind energy development.	[153]
Technical	Benefit	Integration into smart grids can increase efficiency and reliability.	[105]
		Beneficial to grid stability.	[271]
	Risk	Intermittency issues and grid stability challenges due to weather dependence.	[181]
	Advantage	Efficient and sustainable form of energy conversion.	[368]
	Drawback	High risk of system construction and O&M.	[368]
		Weather dependency of wind energy.	[17], [244]
		Technological limitations of offshore wind in deep waters.	[38]
Legal	Barrier	Ownership issues of wind resources.	[153]
General	Driver/ Barrier	listed a wide range of drivers and barriers found for wind energy growth, which in total can be categorized as following: a) Technological, b) Technical potential, c) Social, d) Regulatory, e) Political, f) Environmental, g) Economic and h) Combination.	[382]

Table 11: Summary of risks, benefits, drivers and barriers for wind energy from Category 3 articles

The articles in Category 3 offered a broader perspective on renewable energy transitions, shedding light on various environmental, economic, social, technical, legal and general aspects. While they did not focus specifically on Norway, these findings provide valuable context for understanding the broader dynamics at play.

4.2.3.1 Environmental Topic Area

Wind energy offers advantages over fossil fuels by reducing environmental impacts (Arias et al, 2023). It represents a cleaner form of energy conversion (Yang et al, 2023). However, there are potential risks to ecosystems, biodiversity, and landscapes, as well as concerns about noise pollution (Alpízar-Castillo et al, 2022; Karasmanaki, 2022; Karasmanaki & Tsantopoulos, 2021; Lamnatou et al, 2024). Challenges arise from the complexities of marine environments, including issues of inefficiency and instability in power conversion and transmission (Yang et al, 2023).

4.2.3.2 Economic Topic Area

Wind energy development can stimulate job creation and economic growth, particularly in coastal regions (Lamnatou et al, 2024). However, transitioning to wind energy may result in job displacement within fossil fuel sectors, impacting communities reliant on these industries (Arias et al, 2023). Moreover, as discussed in the work by Yang et al, (2023), the high construction and operational costs of wind energy systems pose economic challenges.

4.2.3.3 Social Topic Area

Wind energy can improve quality of life for communities, with potential for reduced public opposition to floating offshore wind farms due to their minimal environmental impact (Arias et al, 2023; Bento & Fontes, 2019). Nevertheless, visual annoyance and challenges related to public acceptance remain significant concerns (Karasmanaki, 2022; Karasmanaki & Tsantopoulos, 2021). Social acceptance of wind energy development presents a notable barrier (Jegen & Philion, 2018).

4.2.3.4 Technical Topic Area

Wind energy integration into smart grids can enhance efficiency and reliability, contributing to grid stability (Farmanbar et al, 2019; Piacentino et al, 2019). However, issues of intermittency and grid stability persist due to the weatherdependent nature of wind energy (Lamnatou, 2024). Additionally, technological limitations, particularly in deep waters, pose challenges (Alpízar-Castillo et al, 2022; Bento & Fontes, 2019; Nguyen et al, 2021). In addition, while wind energy is an efficient and sustainable form of energy conversion, it faces significant drawbacks such as the high risks associated with system construction and operations and maintenance (O&M) (Yang et al, 2023).

4.2.3.5 Legal Topic Area

Based on the work by Jegen and Philion (2018), Legal ownership issues regarding wind resources present barriers to wind energy development.

4.2.3.6 General Topic Area

According to the paper by Zwarteveen et al (2020), the growth of wind energy faces a range of drivers and barriers, including technological, technical potential, social, regulatory, political, environmental, and economic factors which has discussed widely in the mentioned paper.

4.3 Analysis of the result

Our research aimed to investigate the focus of expert discussions on the risks and benefits of wind energy in Norway following the 2016 Paris Agreement. Despite an extensive systematic review of the literature, we found no articles directly addressing this specific topic (Category 1), revealing a significant gap in the current academic discourse. However, our analysis of related literature (Categories 2 and 3) still provides valuable insights that contribute to the broader understanding of renewable energy transitions, particularly in the context of wind energy in Norway. In the following the main key findings and implications of this thesis are listed.

4.3.1 Literature Gap in Category 1

The absence of Category 1 articles underscores a critical gap in the academic literature. This gap highlights the need for focused research on the risks and benefits of wind energy specific to Norway. Future studies should aim to fill this void by conducting detailed analyses and case studies that explore the unique geographical, social, and economic contexts of wind energy development in Norway. This will not only aid policymakers and stakeholders in making informed decisions but also contribute to the global discourse on renewable energy transitions.

4.3.2 Insights from Literature in Category 2

Although Category 2 articles did not directly address our primary research question, they offered important perspectives on the broader context of wind energy in Norway. These studies highlighted several key themes:

a) *Incentives and Policy Measures:* Effective policy frameworks and economic incentives are crucial for the successful integration of wind energy. Norway's existing policies and potential future strategies were discussed, emphasizing the importance of supportive governmental measures.
b) *Obstacles and Challenges:* Technical, environmental, and social obstacles were frequently mentioned. The studies pointed to issues such as grid integration, environmental impact assessments, and public acceptance as significant challenges that need to be addressed.
c) *Drivers and Facilitators:* The natural wind resources and technological advancements were identified as major drivers for wind energy adoption. Additionally, the potential for job creation and local economic development were seen as significant benefits.

4.3.3 Broader Context from Literature in Category 3

Category 3 articles provided a broader perspective on renewable energy transitions, offering valuable context for understanding the dynamics at play in Norway. Key findings from these articles include:

a) *Potential Risks:* Job displacement, economic impacts, grid stability challenges, and intermittency issues.
b) *Environmental and Social Considerations:* Environmental benefits, but also concerns about ecosystems, biodiversity, noise pollution, landscape changes, visual annoyance, and public acceptance.

c) *Economic and Technological Factors:* Investment requirements, government support, manufacturing and transportation costs, technological challenges with offshore wind installations, and the need for advanced support structures.

d) *Drivers and Opportunities:* Economic development, job creation in coastal regions, integration into smart grids, and the potential for offshore wind to have lower environmental impacts and face less public resistance compared to onshore installations.

While these findings from Category 3 articles provide valuable context, they often lack a direct connection to the specific Norwegian context or a clear framing within a risk assessment and evaluation framework.

5. Discussion

The primary research question guiding this thesis was "What is the focus of expert discussion after the Paris Agreement (2016) on the risk and benefit of wind energy in Norway as a key energy source to achieve energy transition?" To thoroughly examine this question, we posed two sub-questions:

1. Have they considered more risk or benefit? Or have they looked at both at the same time?

2. What is the frequency of dealing with different categories of risks and benefits (consisting of economic, social, environmental, etc.) among various English sources?

Through our systematic review and analysis of the literature, we found no articles in Category 1 that directly addressed the risks and benefits of wind energy specific to Norway in the post-Paris Agreement era. This absence represents a significant gap in the academic discourse, indicating a lack of focused research on this topic within the defined scope. Due to the lack of relevant studies in Category 1, a comprehensive response to the primary research question and its sub-questions is not feasible.

While we did not uncover studies explicitly evaluating the risk-benefit balance of wind energy in Norway, our review yielded valuable insights from related literature in Categories 2 and 3. However, none of the articles in Category 2 discussed the challenges, barriers, drivers, or incentives concerning the theoretical framework outlined in Section 2, which emphasized the importance of considering complexity, uncertainty, and ambiguity when evaluating risks and benefits according to Renn (2008).

Regarding the frequency of different risk and benefit categories discussed, our analysis revealed some general insights across economic, social, environmental, and technical aspects. However, the specific risk-benefit framing was often implicit rather than explicitly stated, making it challenging to quantify the precise emphasis on risks versus benefits within each category. Moreover, the lack of direct linkages to the theoretical framework presented in Section 2 limits our ability to draw meaningful conclusions about the degree to which these concepts were considered in the existing literature.

As mentioned, the reviewed literature did not explicitly engage with the theoretical framework outlined in Section 2, which emphasized the importance of considering complexity, uncertainty, and ambiguity when evaluating risks and benefits according to the work by Renn (2008). The lack of studies directly addressing these concepts in relation to wind energy in Norway represents a significant gap in the academic discourse.

While some of the identified obstacles and challenges, such as grid integration and public acceptance, could be interpreted as reflecting complexity and uncertainty, the reviewed literature did not explicitly frame these factors within the context of risk assessment and evaluation as described by Renn (2008).

Similarly, the debates surrounding landscape changes and the sense of place could be viewed as representing ambiguities in the risk-benefit evaluation process. However, the reviewed articles did not directly connect these discussions to the theoretical framework's emphasis on considering ambiguities when making judgments about the tolerability and acceptability of risks based on Renn's frame work (2008).

Furthermore, the concept of risk characterization and risk evaluation as distinct components in the risk assessment process was not evident in the reviewed literature. While some articles touched upon economic incentives, environmental concerns, and technological advancements, these were not explicitly framed within the context of risk characterization and risk evaluation as outlined in the theoretical framework.

The lack of direct engagement with the theoretical concepts presented in Section 2 represents a notable limitation in our ability to assess the extent to which the existing literature on wind energy in Norway aligns with or deviates from the established risk assessment and evaluation frameworks.

The findings from Category 3 articles provide valuable context on the broader challenges, opportunities, and dynamics surrounding renewable energy transitions, with some insights potentially relevant to wind energy in Norway. However, these articles do not directly address the primary research question of examining expert discussions on the risks and benefits of wind energy in Norway after the 2016 Paris Agreement.

While the Category 3 literature touches on various potential risks, benefits, drivers, and barriers related to wind energy and renewable energy transitions more generally, these discussions are often not specific to the Norwegian context. Additionally, the framing of these factors is typically not explicitly centered around a structured risk assessment and evaluation framework.

Regarding the first sub-question of whether more risks or benefits were considered, the Category 3 findings present a relatively balanced perspective, highlighting both potential risks (e.g., job displacement, grid stability challenges, environmental impacts) and potential benefits (e.g., economic development, reduced emissions, integration with smart grids). However, the lack of a direct focus on Norway limits the relevance of these findings to the specific research questions.

For the second sub-question on the frequency of different risk and benefit categories, the Category 3 literature covers a range of economic, social, environmental, and technical factors. However, as Category 3 does not encompass discussions pertaining to the geographical context of Norway, addressing of this sub-question is no longer relevant.

The Category 3 literature generally does not engage directly with the theoretical framework outlined in Section 2, which emphasizes the importance of considering complexity, uncertainty, and ambiguity when evaluating risks and benefits based on Renn's work (2008). While some of the identified factors, such as grid integration challenges and public acceptance concerns, could be interpreted as reflecting complexities and uncertainties, these connections are not explicitly made within the reviewed articles.

Similarly, the discussions surrounding landscape changes and visual impacts could be viewed as representing ambiguities in the risk-benefit evaluation process, but the reviewed literature does not directly connect these factors to the theoretical framework's emphasis on considering ambiguities.

The distinct components of risk characterization and risk evaluation outlined in the theoretical framework by Renn (2008) are also not evident in the Category 3 literature. While some articles mention economic incentives, environmental concerns, and technological advancements, these factors are not explicitly framed within the context of structured risk characterization and risk evaluation processes.

Overall, the Category 3 literature provides valuable context on the broader landscape of renewable energy transitions but does not directly address the specific research questions or engage with the theoretical framework outlined for this study.

The absence of studies directly addressing the risks and benefits of wind energy in Norway, as well as the lack of explicit engagement with the theoretical framework outlined in Section 2, likely stem from several factors:

a) *Research Focus and Priorities:* The academic discourse on wind energy in Norway may have been shaped by different research priorities and foci. While our study aimed to investigate the risk-benefit balance through the lens of the theoretical framework, existing research efforts may have concentrated on other aspects, such as technical feasibility, economic viability, or public acceptance. This misalignment in research priorities could explain the gap in studies directly addressing our research questions and the theoretical concepts we outlined.
b) *Disciplinary Boundaries:* The theoretical framework we presented draws upon concepts from risk assessment, and decision theory domains. It is possible that the existing literature on wind energy in Norway has been primarily rooted in other disciplines, such as engineering, economics, or social sciences, leading to a disconnect between the theoretical foundations we emphasized and the actual research approaches employed in the reviewed studies.
c) *Limited Interdisciplinary Collaboration:* Addressing the risks and benefits of wind energy in a comprehensive manner requires interdisciplinary collaboration and integration of perspectives from various fields, including risk analysis,

environmental science, economics, and social sciences. The lack of such interdisciplinary efforts in the existing literature could contribute to the observed gap, as studies may have focused on narrower disciplinary perspectives, overlooking the need for a more holistic, risk-based assessment.

d) *Contextual Factors:* The unique geographical, social, and political context of Norway may have influenced the research landscape on wind energy. Factors such as Norway's historical reliance on hydropower, public debates surrounding environmental and social impacts, and policy priorities could have shaped the research questions and approaches taken in the existing literature, potentially deviating from the theoretical framework we highlighted.

e) *Methodological Challenges:* Conducting comprehensive risk-benefit analyses and integrating theoretical *concepts* like complexity, uncertainty, and ambiguity into empirical studies can be methodologically challenging. Researchers may have faced limitations in terms of data availability, analytical techniques, or resource constraints, leading to a focus on more accessible or tractable research questions rather than directly engaging with the theoretical framework we presented.

By understanding these potential reasons behind the identified gap, we can better contextualize the limitations of the existing literature and highlight the need for future research efforts to bridge this divide between theory and empirical investigation.

6. Conclusions

The systematic review conducted in this thesis revealed a notable gap in the existing literature: 'The absence of studies directly addressing the risks and benefits of wind energy in Norway post-Paris Agreement'. This gap underscores the need for focused research in this area, particularly given Norway's unique position as a leader in renewable energy and its potential for wind energy development. Regarding this, the following directions are suggested for future research regarding wind energy risk-benefit analysis in Norway.

a) *Focused Risk-Benefit Analysis:* Future studies should prioritize conducting detailed risk-benefit analyses of wind energy specific to Norway. This includes evaluating economic, environmental, and social risks and benefits comprehensively. Such studies will provide balanced insights that can guide policymakers, industry stakeholders, and the public.
b) *Integration of Risk Science:* Incorporating risk science methodologies into the analysis of wind energy can offer a systematic approach to understanding potential hazards and uncertainties. Risk science can help quantify and mitigate adverse effects, ensuring that the benefits of wind energy development outweigh the risks.
c) *Interdisciplinary Approaches:* Given the multifaceted nature of wind energy impacts, interdisciplinary research is essential. Combining insights from environmental science, economics, social sciences, and engineering can lead to a more holistic understanding of wind energy's role in Norway's green transition.
d) *Longitudinal Studies:* Long-term studies that track the development and impacts of wind energy projects over time will be valuable. Such studies can monitor changes in public perception, environmental impacts, and economic outcomes, providing data that can inform adaptive management strategies.
e) *Comparative Analyses:* Comparative studies between Norway and other countries with similar geographic and climatic conditions can yield valuable lessons. Understanding how different regions address the risks and benefits of wind energy can highlight best practices and innovative solutions applicable to Norway.

In conclusion, while our systematic review did not yield direct answers to our research questions, it provided valuable insights into the broader context of wind energy in Norway. The findings underscore the importance of continued research and discussion in this field, particularly focused on understanding the unique risks and benefits associated with wind energy development in the Norwegian context. Addressing the identified literature gap will be crucial for advancing Norway's renewable energy goals and contributing to global efforts to transition to sustainable energy sources.

By highlighting these areas for future research and emphasizing the interconnected nature of policy, technology, and societal factors, our thesis contributes to the ongoing discourse on renewable energy transitions and provides a foundation for future studies to build upon.

Addressing the identified literature gap through focused research on the risks and benefits of wind energy in Norway is imperative. Such research can provide the necessary insights to harness the potential of wind energy while mitigating its risks. By integrating risk science and adopting interdisciplinary approaches, future studies can contribute significantly to the sustainable development of wind energy, ensuring that it plays a pivotal role in Norway's energy landscape.

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