Energy Policy Integration for Sector Coupling: A Scoping Review

Tuomas Vanhanen
Electrical Engineering
Tampere University
Tampere, Finland
tuomas.vanhanen@tuni.fi

Minna Hanhijärvi
International Politics
Tampere University
Tampere, Finland
minna.hanhijarvi@tuni.fi

***Abstract*—Energy policy integration aims at integrating the design and implementation of policies in line with EU decarbonizing goals across the energy system while considering diverging sectoral policy subdomains. Successful sector coupling enables linking variable renewable energy sources with end-use sectors, enabling higher efficiency, lower consumer costs, and the realization of climate targets.**

In this review paper, we investigate how energy policy integration is applied in the context of sector coupling, with a focus on the heating sector. We scoped in total 84 peer-reviewed articles from Scopus and Web of Science for 2018–2024 with a sample of 25 articles for the final analysis.

The findings reveal that the combined approaches to policy integration and sector coupling are diverse, indicating the novelty of the concept and its application. Further research could analyze the success of current sector coupling policies and design novel integrated instruments to realize cross-sectoral synergies.

***Index Terms*—Decarbonization; Energy policy analysis; Policy integration; Sector coupling, Energy System Integration**

I. INTRODUCTION

Achieving carbon neutrality of the power sector is regarded as the key pillar of the deep decarbonization of the European energy systems and the economy. European countries have framed several actions to enhance decarbonization, including the European Green Deal package [1], the EU emissions trading system, and national energy and climate plans. Global initiatives such as the Paris Agreement guide policymaking. In response to Russia's war in Ukraine, the EU put forward the detailed REPowerEU plan in May 2022 to phase out Europe's dependency on fossil fuel imports from Russia, massively accelerating and scaling up renewable energy generation [2].

For policymakers, the challenge is to ensure the design and implementation of cross-cutting policies that transfer the zero-carbon goals into the energy system while considering diverging sectoral goals, interests, and policies [3]. The EU strategy for Energy System Integration (2020) [4] aims to integrate large amounts of variable renewable energy to end-use sectors of the economy. This means converting power to heat, gas, and liquid fuels, thus creating interfaces between energy vectors on an unprecedented scale. Consequently, more cross-domain coordination in energy policymaking – i.e. policy integration – is needed to avoid sub-optimization of the vectors' distinct policies. In addition, the policy subsystems affect each other in the energy transition [5], whether coordinated or not. Successful sector coupling is expected to result in higher overall energy system efficiency, lower consumer costs, and the realization of climate targets [4]. Sector coupling seems also to provide greater society-level value in integrating renewable electricity into the economy compared to the parallel strategy of cross-border electricity grid expansion, although both should be promoted [6], [7].

A. Policy integration

The concept of policy integration was first defined by Underdal [8] in the 1980s as an attempt to define and distinguish an integrated policy from other policymaking as a response to the demand for "integrated marine policy". Building upon that work some 20 years later, Lafferty and Hovden [9] developed the concept of environmental policy integration. They created an analytical framework where environmental policy integration is divided into vertical and horizontal dimensions. The horizontal dimension describes how "a comprehensive cross-sectoral strategy for integration" is carried out by a central authority, while the vertical dimension concentrates on specific governmental sectors and the implementation of environmental objectives within their core policy objectives [9]. Another ten years later, along with climate change-related policymaking, the concept of Climate Policy Integration gained a footing. Other policy integration focus areas have emerged, including, e.g. biodiversity integration [10].

Closely related to environmental and climate policy integration, energy policy integration has more recently been defined by Tosun and Peters [11] as "non-energy IGOs [Intergovernmental organizations] referring to energy concerns in their organizational goals". Since variable renewable energy

is mostly carried in the form of electricity, it is appropriate to investigate how the policy target of integrating the variable generation of electricity – i.e. sector coupling – is accounted for in other subsectors of the energy domain, namely heating, liquid fuels, and gaseous fuels such as natural gas and the fast-growing hydrogen sector. We view the integration of sector-coupling policies into the heating domain as an application of the energy policy integration concept in the context of a specific policy subsystem. This is illustrated in Figure 1.

B. Horizontal and vertical policy integration

We apply the division to the horizontal and vertical policy integration of Lafferty and Hovden [9] as the basis of our review. The horizontal connection – or coupling – of policy subdomains has been previously analyzed, e.g., in the context of health sciences by Trein [12], clean energy transition in California by Meckling and Goedeking [5], and energy transition and national security in small countries by Kivimaa and Sivonen [13].

Whereas the EU strategy for Energy System Integration represents a horizontal initiative to coordinate across sectors and policy domains, a vertical policy integration approach focuses on whether and how a single sector or vector has integrated the policy domain across governance levels. Vertical policy integration has previously been analyzed, e.g., by Huang [14] in the case of solar water heating in Shandong Province in China, and by Zepa and Hoffmann [15], who found that the supranational sustainability targets for the energy sector do not fully penetrate the state and local levels in Latvia.

C. Policy mixes

There are several frameworks for analyzing policy subdomains. In this paper, we apply the policy mix concept presented by Rogge and Reichardt [16]. They propose that the policy mix consists of the policy process, elements (policy strategy and instrument mix), and characteristics (such as the consistency of elements). We focus our analysis on the elements.

D. The research question

This paper aims to show how the concept of policy integration and the practices of the policy integration framework are applied to sector coupling. In other words, we aim to map the recent literature on energy policy integration in the context of sector coupling. We focus on one energy vector – heating. Heating is at the core of sustainable development goals. It is also a domain where sector coupling has already been applied in practice in many EU member states, e.g., with heat pumps in individual houses and in district heating systems; hence, it provides a solid case example of current developments.

To address the goals of our study, the main research question is formulated as follows: **How is the theory of policy integration applied in the context of sector coupling in the energy domain?** We delved into one major application area of sector coupling, namely the electrification of heating. Hence, our sub-question is: **How is the policy integration concept applied to sector coupling in the heating (and cooling) sector?**

II. METHOD

To answer the research questions, we conducted a scoping review of contemporary scientific literature for 2018–2024. We applied the essential steps of a scoping review method: we used a protocol and inclusion-exclusion criteria and conducted a literature search of two databases with two persons screening the search results, and conducting a quality appraisal [17]. The application of these steps in this paper is described in detail in section II.B. The protocol is available in Appendix A.

A. Definition of a scoping review

The scoping review methodology is a tool to systematically map existing literature. While the aim of a "comprehensive systematic review" is to actively synthesize data from multiple study designs, a scoping review aims at determining what data is available and visualizing the "range of located evidence".[18]

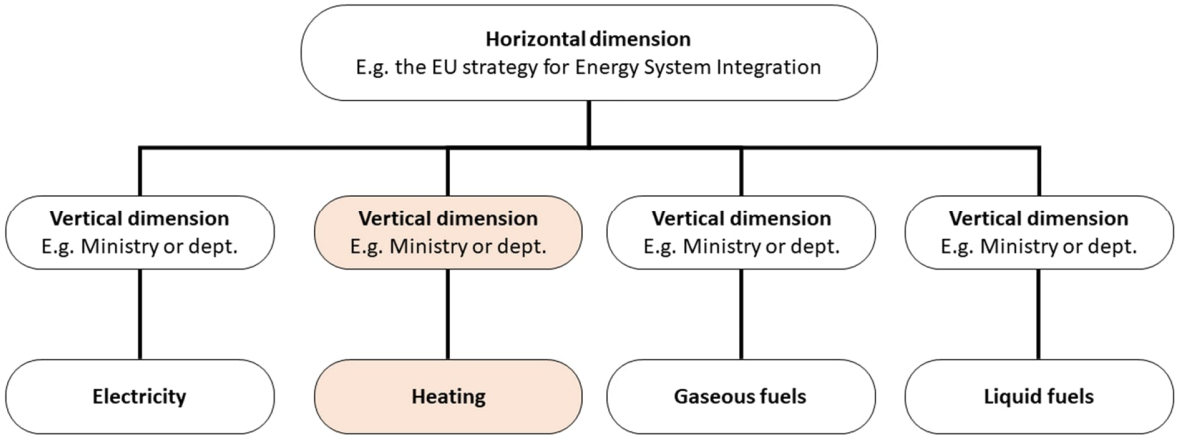

Figure 1. Energy Policy Integration. Horizontal and vertical dimensions based on energy vectors. Modified from Lafferty and Hovden, 2003.

B. Search strategy

Sector coupling is a rather new concept, and prominent literature has been published mainly from 2018 onwards [19]. Therefore, we scoped the past five years of comprehensive literature in the energy policy domain to identify approaches to sector coupling. We focused on peer-reviewed scientific literature from the Scopus and Web of Science databases and limited our analysis to studies focusing on the European context. The selection of search terms was based on pre-reviews and own expert judgement, supported by the literature. Trein et al. [20], for example, found that the term *policy integration* is clearly the most common of its synonyms, followed by *policy coherence*. Consequently, we included these and the following terms in our search string:

ALL= (("policy integration" OR "policy coordination" OR "policy coherence" OR "policy harmonization" OR "cross-sectoral integration" OR "intersectoral coordination") AND ("sector coupling" OR "energy system integration" OR "energy systems integration" OR "electrification")).

The searches were conducted between October 2023 and February 2024. The articles were reviewed through three rounds of searching. After eliminating the duplicate records, the sample of studies resulted in 318 studies. In the first round of searching, we excluded non-journal (and review) articles. After excluding publications that were published before 2018, the results were reduced from 311 to 242. Those with a country affiliation outside the European Union, Norway, and Switzerland were excluded, after which 84 documents remained. Secondly, to limit the sample further, we screened the studies for their title, abstract, and keywords.

The searches resulted in 64 articles that met our inclusion criteria for a more detailed screening. In the third round, the studies retrieved were fully reviewed and analyzed. After an iterative process of checking the relevance, high policy focus, and representation as described in [21], and cross-referencing, we chose the 25 most relevant studies to be included in the analysis. Details of the inclusion and exclusion criteria of each document can be found in the supplementary material.

Some studies were on the edge of inclusion but were left out after scrutiny. These included, for example, studies with a focus on the coupling of sectors through markets. The articles [22], [23], [24], [25] give valuable insight into this topic but we excluded them due to their limited aspect and discussion regarding the policy integration concept. Similarly, although [3], [26] provide an interesting take on policy integration, they only very vaguely address the heating topic, and they were therefore excluded from the analysis.

C. Data extraction

We extracted the data of the final sample of 25 articles by carefully reading and analyzing the full texts. We extracted their approaches according to the following aspects:

i. energy vectors,

ii. end-use sectors, and

iii. policy integration.

Energy vectors refer to electricity, heat, gaseous fuels, and liquid fuels. End-use sectors refer to residential, transport, commercial, and industrial sectors. The concept of policy integration was introduced in section I.A and refers to horizontal and vertical policy integration, policy strategy, and policy instruments.

III. RESEARCH FINDINGS

The results show that the approaches to policy integration in the context of sector coupling range from individual policy evaluation to the assessment of policy mixes, and from the holistic analysis of policy processes to techno-economic evaluation with cross-sectoral policy representation.

Next, we provide the results of the data extraction of the 25 scientific papers that were included for detailed analysis, as described in Section II.C. An extensive table representation of the extracted data is in Appendix B.

A. Approaches to energy vectors

First, a holistic approach includes all or most of the vectors in an analysis, as in [27], [28], [29], [30], [31], [32]. These articles utilize quantitative methods (energy system modelling) [28], [29], [32], and qualitative approaches such as discourse network analysis [27], a form of literature review method [30], [33], and an analysis based on an advocacy coalition framework theory to assess a policy process [31].

The second approach is to include the vectors partially in the analysis. Several articles consider electricity and heating as central in their analysis [34], [35], [36], [37], [38], [39], [40], [41], while the remaining papers focus exclusively on district heating [42] and biogas, the latter mentioning electricity in the context of biogas-based power and heat production and certificates of origin [43].

Third, a group of studies [44], [45], [46], [47] approach the energy domain with alternative framings instead of energy vectors. For example, Behnke and Hegele [44], in the case of Germany, determine energy-relevant policy sectors to include economic and environmental sectors. They do not include an analysis of actual energy vectors, but rather analyse policy sectors or domains. They claim that “energy policy in Germany is not clearly assigned to or established as one policy sector”. Karlsson et al. [47] base their review on three main categories (instead of energy vectors): renewable energy supply, energy savings and efficiency, and greenhouse gas sinks.

B. Approaches to end-use sectors

The most holistic approach is provided by some of the same articles that provided holistic approaches to vectors, namely: [29], [31], [32], [36]. The treatment of the end-use sector varies, and [32], [36] include all end-use sectors in their modelling approach.

On a different note, Muscat et al. [45] focus on five policy domains that partly overlap with end-use sectors: “waste, bio-based industry, environment, renewable energy and agro-food”, and state that these are important for the bioeconomy, the focus of their study. Moroni and Tricarico [34] discuss the concept of the polycentric energy system and the *end-user* perspective, but do not exclusively differentiate between end-use sectors.

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C. Approaches to Policy Integration

All the 25 papers analyzed contribute to the policy integration analysis. However, a group of nine articles explicitly include an analysis of policy integration, policy coordination, or policy coherence [31], [32], [40], [43], [44], [45], [47], [48], [49]. Details are presented in Table 1.

A notable finding is that all the articles that explicitly address the concept of policy integration include aspects of policy strategy or targets, or both. Policy instruments were less focused on. The horizontal approach of policy integration prevailed over the vertical approach.

Two reviews made their way to this group: Chrysikopoulos et al. [40] found insights on policy coupling and policy synergy in the context of green certificates. Karlsson et al. [47] found two favorable outcomes of climate policies related to energy: improved economic and organizational performance, e.g., via the reduced cost of energy, and improved energy security. Karlsson et al. also note that a lack of focus on policy integration is among the top explanations for the limited understanding of climate policy co-benefits.

Aboltins and Jaunzems [43] provide a horizontal analysis of climate policy integration in the national climate and energy plan in Latvia. Similar to Chrysikopoulos et al. [40], they extend their analysis to a more detailed policy instrument level, despite their horizontal approach.

Behnke and Hegele [44] focus on the analysis of the policy process and target setting entailing both the horizontal and vertical approaches in the context of the energy transition in Germany. They base their analysis on multi-level governance theory and the notion of loose coupling between policy subsystems. Similarly, von Malmborg [31] analyses the process of how the energy efficiency-first principle was prepared. He offers several insights to policy coordination through the lens of the advocacy coalition framework.

All the three articles with a vertical approach to policy integration analyze policy instruments. Gustafsson and Anderberg [48] investigated policies on biomethane in an integrative manner, covering several end-use sectors. They refer to policy coherence and stability as something that is lacking from the biogas niche and propose the energy security target as a means for biogas diffusion.

Tsiropoulos et al. [32] conducted a holistic techno-economic analysis on electrification under different policy targets with a strong focus on large scale biomass use. Koronen et al. [49] focused on the ITC sector concluding that only a few EU initiatives affect data centers directly and that electricity taxes and levies, which are decided on the national level, have an indirect yet strong effect on data center profitability.

I. Discussion

The findings reveal that policy integration and sector coupling are approached mainly as separate fields of research: out of the sample of 25 articles analyzed, only nine explicitly include an analysis of the policy integration concept. The rest of the sample articles seek to include policy aspects in their analysis and extend their work across several energy vectors and sectors. This in practice is an analysis of policy integration, since, for example an energy system model that analyses the impacts of cross-sectoral policy targets with a quantitative model, as in [50], *de facto* quantifies the impacts of policy integration. The inclusion of the policy integration or policy coherence method to such studies would enhance the author's pursuit of providing policy advice, as it would guide the study to consider the probably contrasting targets that the sectors already have in place. This could be done by including different policy targets and evaluating their effects, as demonstrated by [29], but the work could be further extended by including scenarios with different policy instrument mixes that aim to realize cross-sectoral synergies.

TABLE 1. REVIEW FINDINGS FOR POLICY INTEGRATION.

Review findings for policy integration						
Main author(s)	***Publishing year***	***Explicit policy integration***	**Approach**		**Policy mixes**	
			Horizontal	***Vertical***	***Strategies, Targets***	***Policy instruments***
Aboltins and Jaunzems	2021	x	x		x	x
Chrysikopoulos et al.	2024	x	x		x	x
Behnke and Hegele	2024	x	x	x	x	
Karlsson et al.	2020	x	x		x	
Muscat et al.	2021	x	x		x	
von Malmborg	2023	x	x		x	
Gustafsson and Anderberg	2023	x		x	x	x
Koronen et al.	2020	x		x	x	x
Tsiropoulos et al.	2022	x		x	x	x

The combined approaches are highly diverse, indicating the novelty of the policy integration concept and its application. The literature on policy integration, as described in Section I.A, indicates that policy integration studies are often qualitative. By contrast, we found that sector coupling-related policy integration research shows several examples of quantitative studies and analyses of the impacts of differing policy choices. This might be due to energy system models being an established tool to conduct energy system analyses. Since we only fully analyzed studies that discuss the heating sector, many of our examples addressed power-to-heat applications. It is probable that we would have found more quantitative policy analyses, or different approaches, by extending our search to, e.g., electric vehicles and their policy subdomain – another prominent field of research.

We propose that future research should aim to systematically determine to what extent policy integration in the energy domain has achieved its intended goals, e.g., in the case of the European Energy System Integration strategy, and combine these data with qualitative research regarding policy processes, policy evaluation, and policy implementation. Such an analysis would be in line with the key recommendations of the previous studies particularly by focusing on research that combines quantitative with qualitative research methods in policy studies where qualitative studies prevail [52], and strengthening the focus on policy evaluation [20]. This type of study could include analyses of the costs and benefits that a policy change in one subsystem induces on other policy subsystem actors. For example, the change in electricity tax also affects the heating domain, but the question is to what extent. Such trans-subsystem policy feedback also mobilizes existing actors, creates new actors, and crowds in other actors, as described by Meckling and Goedeking [5], which arguably has implications for societal aspects, such as employment.

Heating-related analyses generated a multilevel perspective, which allows vertical policy integration analysis. It might be useful to focus research activities on the district heating domain and power-to-heat applications in general and analyze the change in the system-level efficiency of the energy system under different policy mixes. Changes in the policy mix greatly affect the policy outcomes due to the competition between district heating, individual heat pumps, and other options. Scenarios could be developed for analyzing novel integrated policy instruments, the harmonization of policy instruments, or the coordination of policy instruments for electricity, heat, gases, and liquid fuels, in accordance with the work by Hjalmarsson [51].

Other topics for future research include the Energy Efficiency First principle, and the evaluation of the effects of this policy on different energy policy subsystem actors. This analysis could consider the arguments of Ollier et al. [46], who claim that there is some competition between renewable energy and energy efficiency targets, and that higher renewable energy targets would be a preferable strategy for the EU. Here, the work by von Malmborg [31] would make a fine starting point to build upon.

A. Limitations

We followed the main steps in conducting the scoping review (see [17]). Still, some potential limitations are worth discussing here. For example, although we carefully considered the extensive work of Trein et al. [20] on policy integration to define a comprehensive set of search terms, due to the diversity of the research field, some other relevant studies might have been found with other terms. Although the databases we searched are well-established and among the largest available, our focus on European studies has inevitably excluded relevant studies that focus on other geographical areas.

Our focus on recent research is reasonable based on the relative novelty of the sector coupling concept, which is demonstrated by, e.g. Jamasb and Llorca [53], who claim that the literature on the economics of energy system integration was "non-existent" before their work, which was published in January 2019. Moreover, Ramsebner et al. [19] found that sector coupling established itself in the literature in 2019. Still, a wider temporal scope to our review could have allowed relevant studies on policy integration literature to be included that might offer insights on trans-subsystem policy coordination in the energy domain without referral to sector coupling.

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Appendix A – Additional details of the method

Protocol

Search Strategy

- Bibliographic databases to be searched: Scopus, Web of Science
- Journals or websites that will be hand searched for relevant articles: N/A
- Experts or key stakeholders being contacted for additional grey literature or research: N/A
- Forward or backward citations: N/A

Eligibility Criteria

- Inclusion criteria:
  - Energy system integration or sector coupling or their synonyms or applications are mentioned.
  - Includes policy integration or their synonyms.
  - Abstract shows a clear and outspoken focus on energy policy.
  - The article's full text shows analysis of one or more policy instruments / interventions.
- Exclusion criteria:
  - The article doesn't show clear focus on assessment of policy interventions' effect on energy system integration or sector coupling, despite using the keywords.
  - Article is not published during the correct timeframe.
  - Article is not peer-reviewed.
  - Although the article includes one or more policy instruments, they are not relevant to energy system integration or sector coupling.
  - The article merely refers to being policy relevant but does not produce any qualitative or quantitative assessment of policy instruments relevant to energy system integration or sector coupling.
  - Focus is outside of the European Union.

Data extraction

- Database, Author(s), Year of publication, Journal, Doi
- Level of policy focus (high/low), reasoning for level of policy focus, other reason for exclusion or inclusion
- Energy Vectors and End-use Sectors included in the study
- Approach to Policy integration, vertical and/or horizontal policy integration, if strategies and/or policy targets are analyzed, if policy instruments are analyzed.
- Data extraction to and synthesis in an excel sheet.

Study quality assessment

- Two researchers to go through the data.

Research team member roles

- Members: Tuomas Vanhanen (TV), Minna Hanhijärvi (MH)
- Preparation. Protocol development: TV
- Conduct searches and article selection. Review of Abstracts: TV, MH
- Data collection. Review and analysis of all included articles: TV. Quality control and editing: MH.
- Synthesis. Synthesis of analysis: TV, MH
- Write manuscript. Original draft: TV, review and editing: MH.

Results

- Main results presented in table format based on the excel. Categorization of results if applicable.

References.

- The protocol has been reproduced and modified from: Review Protocol Template by Sarah Visintini (licensed under a CC-BY-NC-SA 4.0). Available at: https://cdr.lib.unc.edu/downloads/g158bs88s. Template extracted in October 2023.

Appendix B – Main findings in table form.

TABLE 2. REVIEW FINDINGS FOR ENERGY CARRIERS, END-USE SECTORS, AND POLICY INTEGRATION. THE ABBREVIATIONS ARE EXPLAINED AS FOLLOWS: IN ENERGY CARRIER, E = ELECTRICITY, H = HEATING, G = GASES, L = LIQUID FUELS. IN END-USE SECTORS, R = RESIDENTIAL, T = TRANSPORT, C = COMMERCIAL, I = INDUSTRY. IN POLICY INTEGRATION, PI = EXPLICIT POLICY INTEGRATION, HO = HORIZONTAL, VE = VERTICAL, ST = STRATEGY AND TARGETS, IM = INSTRUMENTS.

Main review findings		**Energy carriers**				**End-use sectors**				**Policy integration**				
Main author(s)	***Publishing year***	***E***	***H***	***G***	***L***	***R***	***T***	***C***	***I***	***PI***	***HO***	***V***	***ST***	***IM***
Aboltins and Jaunzems	2021	(X)	X	X	X		X			X	X		X	X
Bareiß	2020	X	X						X		X		X	
Behnke and Hegele	2024	N/A				N/A				X	X	X	X	
Belova et al.	2023	X	X	X			X		X			X	X	
Bergaentzle and Gunkel	2022	X	X			(X)		(X)	(X)			X		X
Berger et al.	2020	X	X	X			X		X		X		X	X
Bucksteeg et al.	2022	X	X	X		X		(X)	(X)			X	X	X
Chinaris et al.	2023	X	(X)	X		X	X		X			X	X	X
Chrysikopoulos et al.	2024	X	X	X					X	X	X		X	X
Gorroño-Albizu	2020	X	X	X		(X)	X	(X)	(X)		X			X
Gustafsson and Anderberg	2023	X	X	X	X	X	X		X	X		X	X	X
Gürsan et al.	2024	(X)	X	X		(X)		(X)	(X)		X		X	X
Karlsson et al.	2020	N/A				N/A				X	X		X	
Klöckner and Letmathe	2020	X	X	X	X	X	X	X	X		X		X	
Koronen et al.	2020	X	X	(X)		(X)		(X)	X	X		X	X	X
Moroni and Tricarico	2018	X	X		X	X	(X)	(X)	X		X		X	
Muscat et al.	2021	N/A				X			X	X	X		X	
Ollier et al.	2020	N/A				N/A					X		X	
Ozoliņa et al.	2022	X	X	X	X	X		X	X		X		X	X
Schwanitz et al.	2023	X	X	X	X	X	X		X		X		X	
Sillak	2023	X	X			X	X	X	X		X		X	
Szulecki and Overland	2020	X	X			N/A					X		X	
Tsiropoulos et al.	2022	X	X	X	X	X	X	X	X	X		X	X	X
von Malmborg	2023	X	X	X	X	X	X	X	X	X	X		X	
Yuan et al.	2021	X	X	X		X	X	X	X		X		X	