PRISMA 2020 Main Checklist

Topic	No.	Item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	Section 1, Page 1
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist	
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	Line 37-126
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	Line 163-167
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	Line 169-197
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	Line 140-147
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Line 148-155
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	Line 156-162

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Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	Data extraction was performed independently by two reviewers, focusing on study features, WHR technologies (heat pumps, ORC, Kalina, TES, etc.), and outcomes. Cross-checking ensured consistency; disagreements were resolved by discussion. No automation tools were used.
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	Outcomes sought included energy efficiency (e.g., PUE, COP), CO_2 emission reduction, technical feasibility, and environmental/economic benefits. All reported results aligned with these domains were extracted; qualitative outcomes without numerical data were recorded narratively.
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	Other variables extracted included study characteristics (year, country, source), waste heat recovery technology type (heat pumps, ORC, Kalina, thermoelectric, TES), and application scenarios (district heating, cooling, power generation). Only published data were used; missing or unclear information was not imputed and treated as qualitative reference.
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	Two reviewers independently assessed the methodological quality of all included studies based on relevance, transparency of data, and clarity of reporting. Disagreements were resolved by discussion, with a third reviewer consulted when consensus could not be reached. No formal bias assessment tools were applied given the narrative review nature of this work, and no automation tools were used.
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	No formal quantitative effect measures (e.g., risk ratio, mean difference) were applied, as this review synthesizes findings qualitatively. The primary focus was on technological performance, energy efficiency, environmental benefits, and integration feasibility.
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item 5)).	Studies were grouped by technological category (heat pumps, thermal energy storage, absorption/adsorption cooling, Organic Rankine Cycle, Kalina Cycle, thermoelectric generation, and district heating integration). Eligibility was determined by relevance to data center waste heat recovery.

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	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	No statistical data conversions were necessary; descriptive data and reported results were directly extracted. Missing details were clarified by consulting original references when possible.
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	Line 197, Table 1; Line 402, Table2.
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	Narrative synthesis was employed instead of meta-analysis, due to the heterogeneity of study designs and outcome metrics. The rationale was to provide a comprehensive overview across diverse methods.
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	Potential sources of heterogeneity (e.g., different system boundaries, scales of application, and regional conditions) were qualitatively discussed, but no subgroup analysis or meta-regression was performed.
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	No formal sensitivity analyses were conducted; robustness of findings was addressed by cross-comparing multiple studies and highlighting consistent trends.
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	No formal statistical assessment of reporting bias was conducted. To mitigate potential bias, multiple databases and organizational reports were included, and reference lists of relevant publications were also screened.
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	The certainty of evidence was evaluated qualitatively by considering the consistency of findings across studies, the credibility of data sources, and the maturity of technologies. No standardized grading tool was applied.
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	Page 32

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	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	Several papers on unrelated energy systems were excluded as they lacked relevance.
Study characteristics	17	Cite each included study and present its characteristics.	heat pumps: Line 198-246, thermal energy storage: Line 247-290, adsorption/absorption cooling: Line 291-334, Organic Rankine Cycle: Line 355-402, Kalina cycle: Line 403-439, thermoelectric generation: Line 440-476, district heating: Line 506-574.
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	No formal bias assessment tool was applied, but potential bias was discussed qualitatively, focusing on system boundary assumptions, scale differences, and data availability.
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	Individual studies were summarized narratively, highlighting energy efficiency, carbon reduction potential, and feasibility. No quantitative effect estimates were reported due to heterogeneity.
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	Syntheses grouped by technology type; general low bias observed.
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	No meta-analysis performed; only descriptive synthesis.
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	Heterogeneity sources such as regional climate and technical maturity discussed.
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	No formal sensitivity analysis; robustness ensured through cross-study comparison.
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	Reporting bias was not formally tested, but multiple databases and reference list screening minimized missing results.
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	Certainty of evidence was assessed qualitatively, based on consistency of findings, reliability of sources, and technical maturity.

Topic	No.	Item	Location where item is reported
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	Line 575-631
	23b	Discuss any limitations of the evidence included in the review.	A key limitation lies in the variability of reported performance indicators across studies, as differences in climate conditions, system boundaries, and assumptions hinder direct comparisons. In addition, limited pilot projects restrict the availability of long-term operational data.
	23c	Discuss any limitations of the review processes used.	The review relied primarily on English-language literature, which may exclude valuable findings published in other languages. In addition, the absence of quantitative synthesis (e.g., meta-analysis) limited the ability to derive statistical comparisons.
	23d	Discuss implications of the results for practice, policy, and future research.	Line 632-647
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	N/A
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	N/A
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	N/A
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	This review did not receive any financial or non-financial support from institutions, organizations, or funding agencies. The article processing charge (APC) will be covered by the authors' team independently.
Competing interests	26	Declare any competing interests of review authors.	Line 654-657

Topic	No.	Item	Location where item is reported
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	Line 658-661

PRIMSA Abstract Checklist

Topic	No.	Item	Reported?
TITLE			
Title	1	Identify the report as a systematic review.	Yes
BACKGROUND			
Objectives	2	Provide an explicit statement of the main objective(s) or question(s) the review addresses.	Yes
METHODS			
Eligibility criteria	3	Specify the inclusion and exclusion criteria for the review.	Yes
Information sources	4	Specify the information sources (e.g. databases, registers) used to identify studies and the date when each was last searched.	No
Risk of bias	5	Specify the methods used to assess risk of bias in the included studies.	No
Synthesis of results	6	Specify the methods used to present and synthesize results.	No
RESULTS			
Included studies	7	Give the total number of included studies and participants and summarise relevant characteristics of studies.	No
Synthesis of results	8	Present results for main outcomes, preferably indicating the number of included studies and participants for each. If meta-analysis was done, report the summary estimate and confidence/credible interval. If comparing groups, indicate the direction of the effect (i.e. which group is favoured).	Yes
DISCUSSION			
Limitations of evidence	9	Provide a brief summary of the limitations of the evidence included in the review (e.g. study risk of bias, inconsistency and imprecision).	Yes
Interpretation	10	Provide a general interpretation of the results and important implications.	Yes
OTHER			
Funding	11	Specify the primary source of funding for the review.	No
Registration	12	Provide the register name and registration number.	No

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