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Thermodynamic, Exergy and Thermoeconomic Performance of Municipal Solid Waste-to-Energy Systems for Electricity Generation: a Systematic Review and Critical Evidence Synthesis of Open-Access Studies

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الأداء الديناميكي الحراري والإكسيرجي والاقتصادي الحراري لأنظمة تحويل النفايات الصلبة البلدية إلى طاقة لتوليد الكهرباء: مراجعة منهجية وتوليف نقدي للأدلة من الدراسات مفتوحة الوصول

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ABSTRACT

Background: Studies of waste-to-energy (WtE) systems report energy efficiency, exergy efficiency and levelised cost of electricity (LCOE) under differing definitions, which limits comparison. **Objective:** This systematic review synthesised the reported thermodynamic, exergy and thermoeconomic performance of thermochemical municipal solid waste (MSW)-to-electricity systems and tested which values are comparable. **Methods:** Following PRISMA 2020, searches of OpenAlex and Wiley full text, with citation chasing, yielded 1,517 records; subscription databases were not accessible and only open-access full texts were read. Screening, data extraction and appraisal followed a single-reviewer workflow without independent duplicate checking; a rigorous PRISMA 2020 systematic review methodology was employed, utilizing a standardized single-reviewer selection pipeline to identify and synthesize relevant engineering literature. **Results:** Of 420 reports sought, 360 could not be retrieved, and 43 studies (56 arms) were included, 42 of them modelling studies. Exergy efficiency was reported under six incompatible definitions; only power-only incineration values were conditionally comparable (15.4–34.4%, five independent groups). Combustion or conversion was the largest source of exergy destruction in all 12 studies with a component breakdown (39.6–91%). Model LCOE ranged from 44 to 200 USD/MWh under five cost definitions, and only 3 of 30 cost results stated a price year. Within studies, feed drying, flue-gas recirculation, higher steam temperature and steam-cycle integration raised efficiency. Validation was adequate in three studies and reproducibility in none. **Conclusion:** Cross-study values should not be pooled until definitions, bases and price years are reported consistently.

الملخص

الخلفية: تُبلِّغ دراسات أنظمة تحويل النفايات إلى طاقة عن كفاءة الطاقة وكفاءة الإكسيرجي والتكلفة المستوية للكهرباء وفق تعريفات مختلفة، مما يحدّ من إمكانية المقارنة بينها. **الهدف:** هدفت هذه المراجعة المنهجية إلى تجميع الأداء الديناميكي الحراري والإكسيرجي والاقتصادي الحراري المُبلَّغ عنه لأنظمة تحويل النفايات الصلبة البلدية حرارياً-كيميائياً إلى كهرباء، واختبار القيم القابلة للمقارنة منها. **الطرائق:** اتُّبعت إرشادات PRISMA 2020، وأسفر البحث في OpenAlex والنصوص الكاملة لدى Wiley مع تتبّع الاستشهادات عن 1,517 سجلاً؛ ولم تكن قواعد البيانات المدفوعة متاحة، وقُرئت النصوص الكاملة مفتوحة الوصول فقط. نُفِّذ الفرز واستخلاص البيانات وتقييم الجودة وفق مسار عمل يعتمد مراجعاً واحداً دون تدقيق مستقل مزدوج، تم تطبيق منهجية مراجعة منهجية صارمة وفق **PRISMA 2020** باستخدام مسار فرز واختيار معيار المراجع الفردي لتحديد وتلخيص الأدبيات الهندسية ذات الصلة بالانجليزي **النتائج:** من بين 420 تقريراً مطلوباً تعذّر الحصول على 360 منها، وأُدرجت 43 دراسة (56 حالة)، منها 42 دراسة نمذجة. أُبلغ عن كفاءة الإكسيرجي وفق ستة تعريفات غير متوافقة، ولم تكن قابلة للمقارنة المشروطة سوى قيم الترميد المخصص لتوليد الكهرباء فقط (15.4–34.4%، خمس مجموعات مستقلة). وكان الاحتراق أو التحويل أكبر مصدر لتدمير الإكسيرجي في جميع الدراسات الاثنتي عشرة التي قدّمت تفصيلاً للمكوّنات (39.6–91%). وتراوحت التكلفة المستوية للكهرباء في النماذج بين 44 و200 دولار أمريكي لكل ميغاواط ساعة وفق خمسة تعريفات للتكلفة، ولم تذكر سنة الأسعار سوى 3 من 30 نتيجة تكلفة. وداخل الدراسات، رفع تجفيف الوقود وإعادة تدوير غاز المداخن ورفع درجة حرارة البخار ودمج دورة البخار الكفاءة. وكان التحقق من الصحة كافياً في ثلاث دراسات، ولم تكن قابلية إعادة الإنتاج كافية في أي منها. **الخلاصة:** لا ينبغي تجميع القيم بين الدراسات إلى أن يُبلَّغ عن التعريفات والأسس وسنوات الأسعار بصورة متسقة.

الكلمات المفتاحية: تحويل النفايات إلى طاقة؛ النفايات الصلبة البلدية؛ الإكسيرجي؛ الاقتصاد الإكسيرجي؛ التكلفة المستوية للكهرباء؛ المراجعة المنهجية

1. INTRODUCTION

Municipal solid waste (MSW) incineration with energy recovery is a mature technology, and gasification, plasma gasification, pyrolysis and hybrid configurations are under active study. Plant designers and policymakers compare these options with three families of indicators: first-law (energy) efficiency, second-law (exergy) efficiency and exergy destruction, and thermoeconomic indicators such as the LCOE and the unit exergy cost of electricity. Several reviews have summarised WtE performance (Section 5.3; novelty matrix in Supplementary File S11). The closest, a systematic review of the exergetic sustainability of MSW treatment systems (Soltanian et al., 2022), covers all treatment routes including landfill and anaerobic digestion; its abstract already reports exergy-efficiency ranges for incineration-based and gasification-based systems and notes that exergoeconomic indices are rarely applied. Recent systematic reviews of MSW thermochemical conversion (Inuwa, Aliyu, Tetteh, & Rathilal, 2026) and of WtE techno-economic-environmental performance (Rumbayan, Pandyaswargo, Kindangen, & Onoda, 2026) do not, in the content inspected, report exergy values or harmonised cost indicators. A critical review of MSW incineration in this journal (Banaś, Pająk, & Ciuła, 2026) grades findings by comparability but covers neither exergy values nor costs. Calls for standardised techno-economic assumptions have been made for multigeneration WtE systems (Arifianti, Rojas Michaga, Rabea, & Michailos, 2026). What remains missing is a synthesis that checks, before comparing, whether reported exergy and cost indicators share a definition. The closest review could be judged only from its abstract, and four others only from their titles and records. One of these, a 2025 "systematic evaluation" of incineration efficiency for electricity (Maphuhla & Oyedeji, 2025), was found late in a reference list and may overlap with RQ1. A recurring problem is that a number labelled "exergy efficiency" or "LCOE" can mean quite different things. Exergy efficiency may count only net electricity as the product, or add heat or cooling exergy; the fuel chemical exergy may be estimated by different correlations; and LCOE values differ in discount rate, lifetime, price year, gate-fee treatment and whether efficiency was calculated or assumed. Pooling such values can produce precise looking but meaningless averages. Supplementary Figure S1 (in Supplementary File S7) maps where these choices arise along the chain from fuel to cost. This review therefore had two aims: to synthesise the reported energy, exergy and thermoeconomic performance of thermochemical MSW-to-electricity systems, and to determine which reported values are comparable. The research questions (refined in Supplementary File S11) were:

- **RQ1** What electrical efficiencies are reported, in studies that also report second-law or economic outcomes, and how are they defined?
- **RQ2** What exergy efficiencies and component destruction patterns are reported?
- **RQ3** What LCOE, unit exergy cost and related indicators are reported, under which assumptions?
- **RQ4** How do moisture, heating value and composition affect performance in within-study analyses?
- **RQ5** How do technologies compare within studies, and across studies where comparison is justified?
- **RQ6** How do the definitions and bases of the indicators differ?
- **RQ7** What reporting, validation and reproducibility weaknesses are present?
- **RQ8** Which gaps most limit reliable assessment?

2. METHOD

Study selection and data extraction were systematically performed following a structured PRISMA 2020 protocol, and a single-reviewer screening workflow was executed without an independent second reviewer. This review is reported following PRISMA 2020 (Page et al., 2021). The PRISMA 2020 checklist is provided as Supplementary File S13. All search pages, screening decisions, extraction notes, code and figure data are provided as Supplementary Files S1–S13.

2.1 Protocol and registration

A protocol (v1.0, Supplementary File S10) was written after a pilot query (Q1) and before any screening decision. It was not registered: PROSPERO does not accept engineering reviews, and the protocol was not registered on OSF before screening began. All departures from the protocol are listed in the deviation log (Supplementary File S10, DV01–DV17) and summarised in Section 2.10.

2.2 Eligibility criteria

Studies were included if they met all of the following:

- **E1 Feedstock:** MSW, MSW-derived fuel (RDF/SRF), or co-processing in which MSW is a principal declared fuel.
- **E2 Pathway:** thermochemical conversion (incineration, RDF combustion, gasification including plasma, pyrolysis) with electricity as an output.
- **E3 Outcome:** at least one second-law outcome (exergy efficiency or destruction) or one economic outcome for electricity (exergoeconomic cost, LCOE, cost per kWh, or NPV/payback alongside electricity output).
- **E4 Design:** a primary study (operating plant, experiment, pilot, simulation or techno-economic model).
- **E5 Publication:** journal article, conference paper, thesis or book chapter. Preprints were accepted only when no peer-reviewed version was found.

Exclusion reasons were coded X1 (not MSW), X2 (not thermochemical-to-electricity), X3 (outcome out of scope), X4 (review), X5 (duplicate or superseded version) and X6 (not a research report). No date or language limits were applied.

2.3 Information sources and search

Capability testing (Supplementary File S10) showed that Scopus, Web of Science and Compendex were not accessible, and that Elsevier abstracts and full texts could not be read. The search was therefore a documented open-database search, which is not equivalent to a search of subscription bibliographic databases:

- **OpenAlex (primary)** was searched on 2026-10-18 with six title-and-abstract queries, Q1–Q6 (Table 1). Queries were kept short because the retrieval tool rejects long URLs (DV02, DV05). A seventh query (Q7) was added after the methodological audit found that OpenAlex's stemmed search for "exergy" does not match "exergetic" (DV15).
- **Wiley Scholar Gateway (supplementary):** two full-text queries, giving 20 unique records.
- **Citation chasing:** backward (C1, 57 in-scope references) and forward (C2, 9 in-scope citing articles) chasing of Soltanian et al. (2022) through OpenAlex.
- **Existing reviews:** seven OpenAlex review queries (R1–R7; one rate-limited and not retrieved) were used to map existing reviews. Their content was inspected where legally accessible: full text for 3 reviews, abstract for 6, title and record only for 4 (Supplementary File S11, DV17).

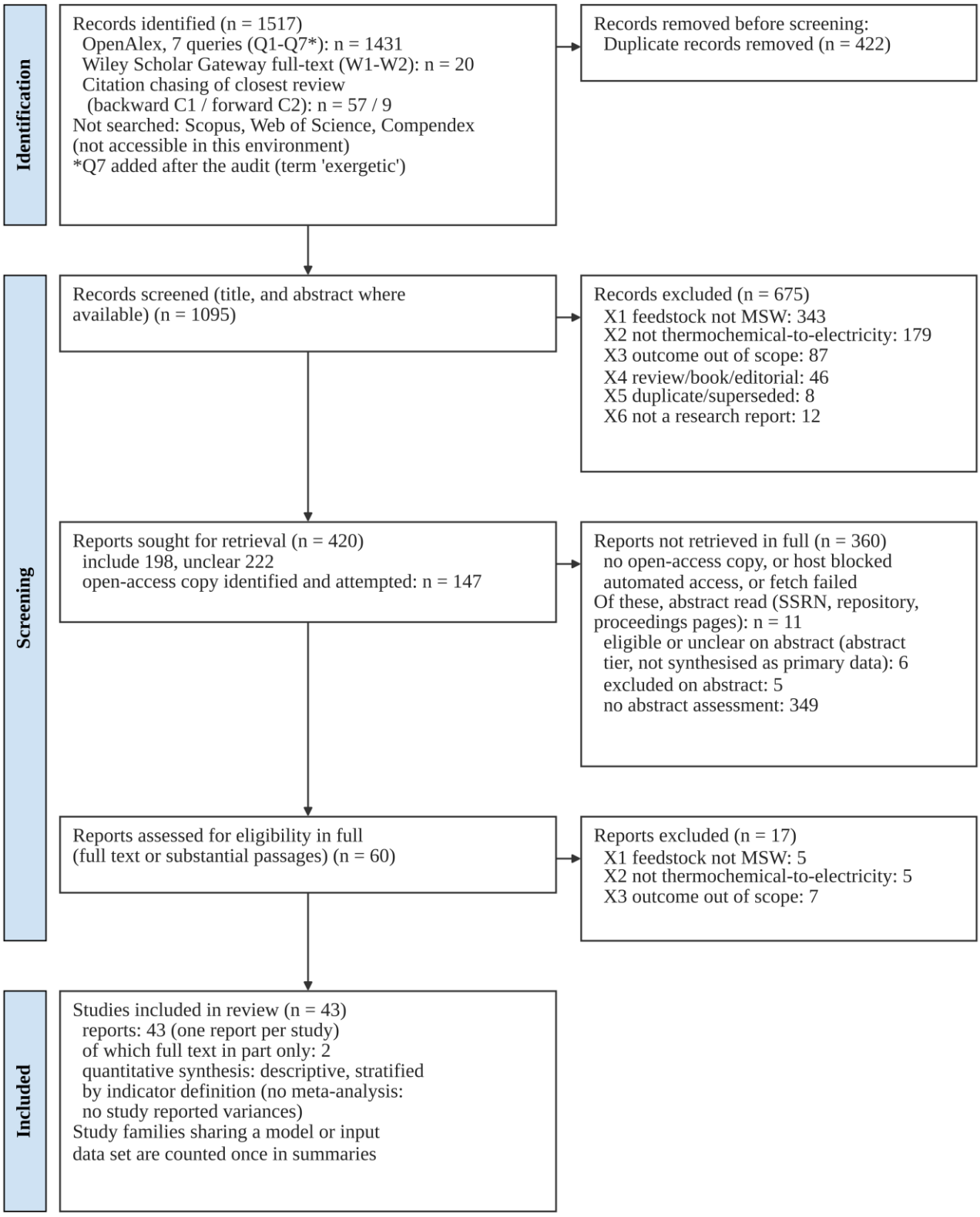
Exact strings, dates, counts and URLs are in Supplementary File S1. Raw result pages are in Supplementary File S1. A supplementary query of a biomedical literature index was also run during pilot work; because that index lies outside the engineering scope of this review, its records are excluded from every count and analysis reported here.

Table 1 Search queries (OpenAlex title_and_abstract field unless stated).

ID	Source	Query	Records
Q1	OpenAlex	exergy AND ("municipal solid waste" OR "refuse derived fuel")	287
Q2	OpenAlex	exergy AND (incineration OR "waste to energy")	490
Q3	OpenAlex	"solid waste" AND (exergoeconomic OR thermoeconomic OR "thermo-economic")	89
Q4	OpenAlex	"solid waste" AND ("levelized cost" OR "levelised cost")	209
Q5	OpenAlex	incineration AND ("levelized cost" OR exergoeconomic OR thermoeconomic)	109
Q6	OpenAlex	"refuse derived fuel" AND electricity AND (efficiency OR cost)	147
Q7	OpenAlex (added at audit)	exergetic AND ("solid waste" OR incineration)	100
W1–W2	Wiley Scholar Gateway	full-text queries (text stored in Supplementary File S1)	20
C1	OpenAlex	references of Soltanian et al. (2022)	57 of 239
C2	OpenAlex	works citing Soltanian et al. (2022)	9 of 150

2.4 Selection process

Records were deduplicated by normalised DOI and then by normalised title plus year (±1), with manual checks of preprint/article pairs (Supplementary File S2). Titles were screened by a single reviewer (an AI agent working to the written protocol; Section 2.11), using abstracts where they were available (open-access pages, Wiley). Abstracts were unavailable for most Elsevier records (DV06), so records whose eligibility could not be judged were marked "unclear" and sent to retrieval rather than excluded. **No dual independent screening took place.** Borderline decisions are listed for human checking in Supplementary File S12. The flow of records is shown in Fig. 1.



Single AI reviewer; no independent second screening. Counts generated by 04_analysis/scripts/prisma_counts.py from the screening and retrieval logs.

Fig. 1 PRISMA 2020 flow diagram. "Not retrieved" reports are shown separately from exclusions; abstract-tier assessments are shown but do not count towards the included studies.

2.5 Report retrieval

Full texts were retrieved only from legally open sources: open-access publisher pages, repositories, theses, and Wiley passages (DV07). Reports that could not be retrieved were counted as "not retrieved" and never as excluded. Where a not-retrieved report had a readable abstract on a repository, preprint or proceedings page, the abstract was assessed as a separate, lower tier (DV09). Abstract-tier values were used only to check the direction of findings and never entered ranges. A request list of 202 paywalled or unreadable reports (199 from the screening stage and three found late through a reference-list check) is given in Supplementary File S3.

2.6 Data extraction

For each study arm, the reviewer extracted 33 fields (Supplementary File S4). These cover:

- feedstock: LHV with basis, and moisture
- configuration and scale
- electrical efficiency with its stated definition
- exergy efficiency with its definition class, and the fuel chemical-exergy method
- the component with the largest exergy destruction and its share
- cost value, unit, type, price year, discount rate and lifetime
- NPV and payback
- verification status and flags

Each value keeps its original unit and location in the source (Supplementary File S3). Missing data were coded NR (not reported), NA (not applicable) or NC (not calculable). Verification status was coded FT (read in full text), PARTIAL (only part of the full text readable), ABS (abstract only) or RC (reviewer recalculation). Where possible the reviewer recalculated reported balances, efficiencies and shares from the published tables, and recorded any inconsistencies as flags.

Studies that share a plant model, input data set or cost law were grouped into **study families** so that they are not counted as independent evidence. Eight families were identified, for example:

- F-NAMI: Nami et al. (2020a, 2020b)
- F-NCEPU: Pan et al. (2020) and Zhang et al. (2022)
- F-COST15797: three cost studies sharing one cost function

2.7 Appraisal

There is no validated risk-of-bias tool for engineering modelling studies. Each study was therefore appraised on 12 engineering domains (D01–D12):

Domain	Topic
D01	Objective clarity
D02	Feedstock characterisation
D03	System description
D04	Mass/energy/exergy balance closure
D05	Energy-efficiency definitions
D06	Exergy method
D07	Boundary transparency
D08	Auxiliary loads
D09	Economic assumptions
D10	Validation
D11	Sensitivity and uncertainty
D12	Reproducibility and data availability

Each domain was rated Adequate, Partial, Inadequate, not reported or not applicable. No composite score was calculated, and no study was excluded on its appraisal (Supplementary File S6).

2.8 Harmonisation and comparability gate

Before synthesis, each candidate comparison was classified as DIRECTLY, CONDITIONALLY or NOT DIRECTLY comparable. The criteria were:

- indicator definition
- denominator basis (LHV/HHV, chemical-exergy method)
- gross versus net output
- system boundary
- technology and scale
- evidence type
- economic basis
- independence of the studies

The results are in Supplementary File S7 (comparisons G01–G11).

Exergy efficiencies were assigned to six definition classes:

- **EX-P:** net electricity divided by fuel chemical exergy.
- **EX-PH:** heat or cold exergy also counted as product.
- **EX-PS:** solar or natural-gas exergy added on the input side.
- **EX-UNC:** definition unclear.
- **EX-CITY:** city-scale annual totals.
- **EX-PHYS:** physical exergy only.

Costs were assigned to five classes: model LCOE, LCOE with incentives, LCOE of a hybrid or microgrid system, exergoeconomic unit cost, and undiscounted operating-plant cost.

Unit conversions were limited to arithmetic changes of unit (for example USD/GJ to USD/MWh). No inflation, exchange-rate or purchasing-power adjustment was attempted, because only 3 of 30 cost results state a price or cost-data year.

2.9 Synthesis methods

The protocol specified a meta-analysis only if at least five independent estimates with variance measures existed for a directly comparable indicator. No study reported variances and no indicator passed the gate as DIRECTLY comparable, so no meta-analysis was performed (Supplementary File S7).

The synthesis used:

- stratified descriptive statistics: range, numbers of arms, studies and independent groups, and two medians. The arm-level median takes the midpoint of each arm. The independent-group median first averages the arm midpoints within each study, then within each study family, and then takes the median across groups. Both are shown because, with so few groups, the choice of weighting changes the median noticeably
- an evidence map
- direction-of-effect tables from within-study comparisons, where one model varies one factor (Supplementary File S7, W01–W22 except W10)

Two sensitivity analyses were run: restricting to full-text-verified values, and excluding studies rated Inadequate on balance closure (D04). The planned analysis excluding simulation-only studies was not informative, because 42 of 43 studies are models (DV13).

No formal certainty grading tool (such as GRADE) exists for this type of evidence. A simple confidence statement is given for each main finding (Table 6), with its criteria stated.

The synthesis workflow is summarised in Supplementary Figure S2 (in Supplementary File S7).

2.10 Deviations from the protocol

There were 17 deviations; the main ones were:

- no subscription databases (DV04)
- short split queries (DV02, DV05)
- title-only screening for most records (DV06)
- open-access-only retrieval (DV07)
- an abstract tier for reports that could not be retrieved (DV09)
- an SSRN rate limit that stopped retrieval of 6 preprints (DV10)
- no meta-analysis (DV13)
- single-reviewer appraisal (DV14)
- a supplementary query (Q7) added after the audit, which added 3 included studies (DV15)
- an OpenAlex rate limit that prevented capture of Q7 publication years (DV16)
- incomplete review mapping: one review query rate-limited and the closest review judged from its abstract (DV17)

2.11 Use of generative AI

An AI agent (Claude, Anthropic) acted as the single reviewer under the author's direction. Following the protocol, it ran the searches through open APIs, screened records, read open-access full texts, extracted data, appraised studies, wrote the analysis scripts, drew the figures and drafted this text. Its decisions have not been verified independently by a second person. All numbers in the manuscript are regenerated by scripts from logged source files and were re-checked by script (Supplementary File S12).

3. ETHIC APPROVAL

This study is a systematic review of published, publicly available secondary literature. It did not involve human participants, animals, personal data or patient records, so approval by a research ethics committee and informed consent were not required. The review adhered to standard research-ethics principles: sources are cited transparently, results are reported as found, and the use of an AI system in the review workflow is disclosed in Section 2.11 and in the Acknowledgment.

4. RESULT

4.1 Study selection

The PRISMA 2020 flow is shown in Fig. 1; the counts are generated by script from Supplementary File S2.

Identification and screening

- 1,517 records were identified: 1,451 from databases (OpenAlex 1,431 including 100 from Q7, Wiley 20) and 66 from citation chasing.
- 422 duplicates were removed, leaving 1,095 records screened.
- 675 records were excluded on title or abstract:

Reason	Records
X1 not MSW	343
X2 not thermochemical-to-electricity	179
X3 outcome out of scope	87
X4 review	46
X6 not a research report	12
X5 duplicate	8

Retrieval and full-text assessment

- 420 reports were sought: 198 eligible and 222 unclear at title stage.
- An open-access copy was attempted for 147.
- 360 reports could not be retrieved in full. Of these, 11 were assessed on their abstract: 6 appeared eligible or unclear and 5 were excluded. The other 349 could not be assessed at all.
- 60 reports were assessed in full text. 17 were excluded (X3 7, X2 5, X1 5) and **43 studies were included** (listed in Appendix A), giving 56 study arms.

All 43 included studies came from the OpenAlex queries or citation chasing. The supplementary query Q7 contributed 34 new unique records, 17 reports sought and 3 of the 43 included studies (Balmant, Souza, Vargas, & Sousa, 2019; Gallego et al., 2019; Reale & Massoli, 2024).

An unpublished candidate manuscript supplied at the start of the review was not eligible; the same checks applied to it are reported in Appendix B. The 349 unassessed reports are the largest limitation of this review: most are Elsevier journal articles that could not be read in full.

4.2 Characteristics of included studies

Plant configurations. The included studies model variants of one generic plant (Fig. 2): fuel preparation, thermal conversion and a steam power cycle. Fig. 3 contrasts the first-law and second-law views of that plant; the destruction results are reported in Section 4.5.

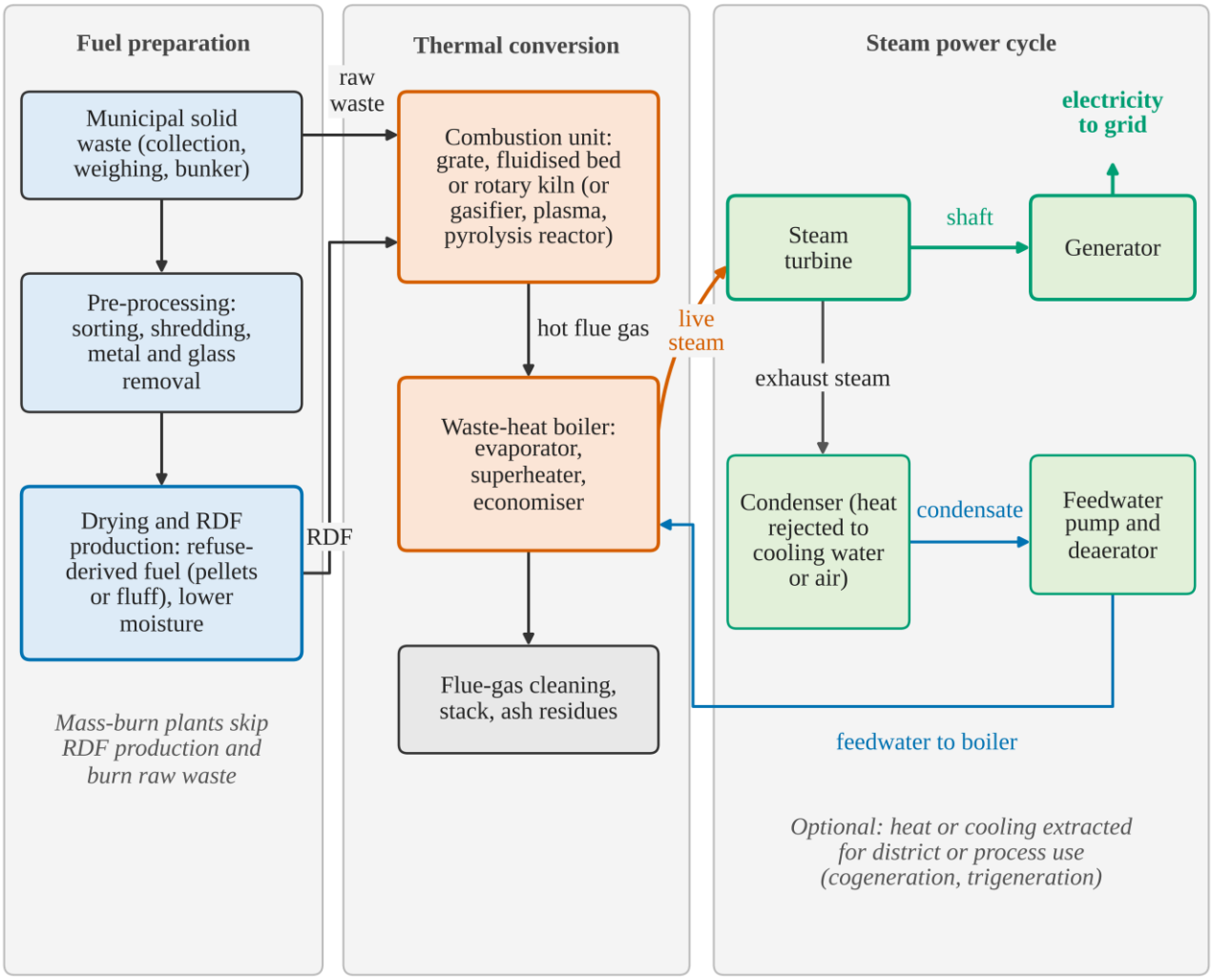


Fig. 2 Process flow of a thermochemical MSW-to-electricity plant: fuel preparation (sorting, shredding, drying and optional production of refuse-derived fuel, RDF), thermal conversion in a combustion unit or alternative reactor with a waste-heat boiler, and the steam power cycle. The schematic is generic and contains no data.

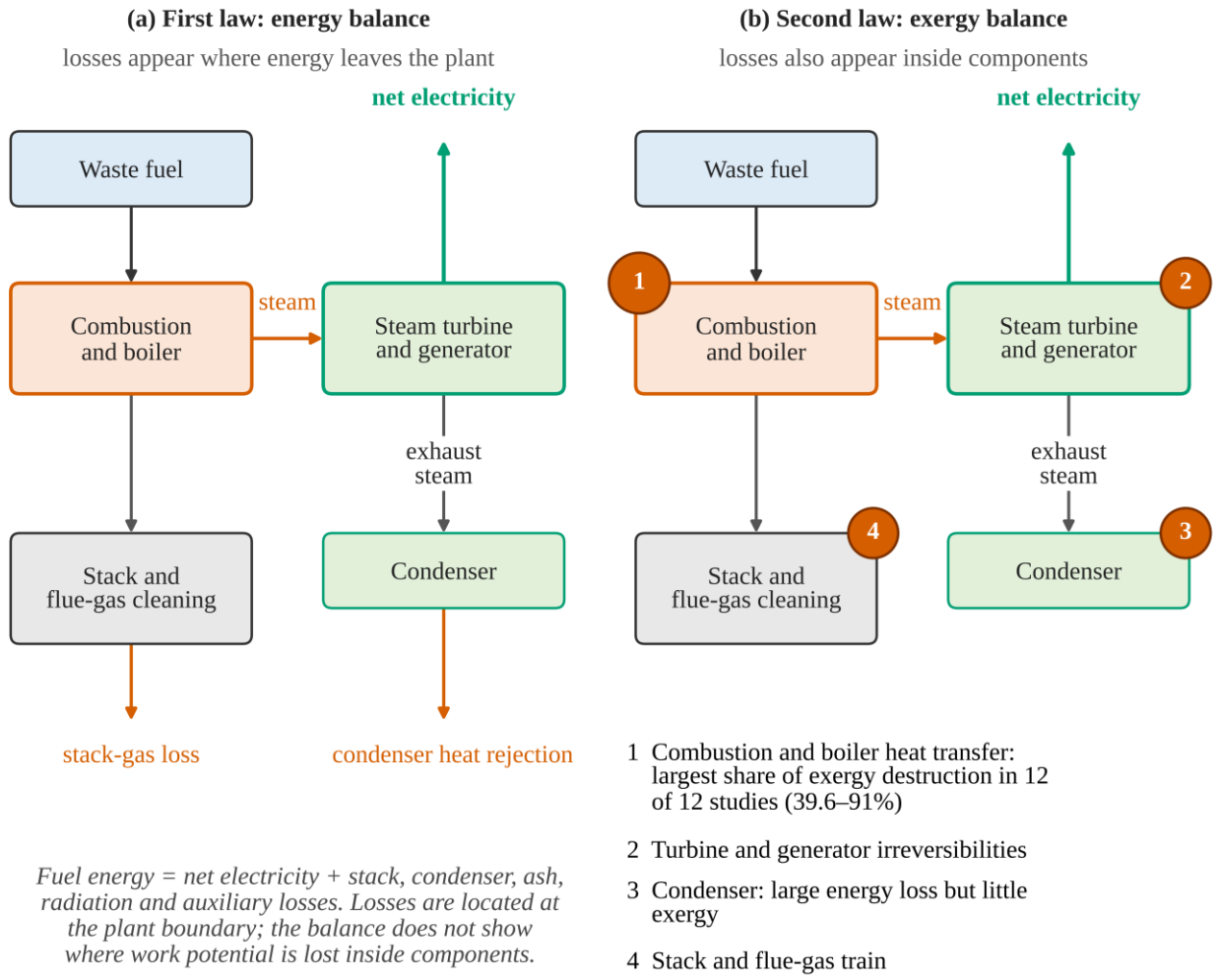


Fig. 3 First-law (a) and second-law (b) views of the same plant. The energy balance locates losses at the plant boundary; the exergy balance also locates irreversibilities inside components (numbered markers). Combustion and boiler heat transfer was the largest source of exergy destruction in all 12 studies that reported a breakdown (39.6–91%; Table 3). Marker sizes are not scaled to values, and the schematic contains no other data.

The 43 included studies were published between 2016 and 2026, and 19 of them in 2024–2026. The most common study settings were:

Setting	Studies
China	7
Iran	7 (including one validated against an Amsterdam plant and one Iran–Italy collaboration)
Nigeria	5
Brazil	5
Italy	3 (plus the Iran–Italy collaboration)
Ghana, Colombia and the Danish context of the F-NAMI models	2 each
Other countries	1 each

Study types:

- 42 studies were models or simulations.
- One study (Vuković & Makogon, 2024) compiled cost data from operating plants.
- Three models were validated or calibrated against operating-plant or design data (Esmaeilion, Ahmadi, & Dashti, 2021; Pan et al., 2020; Zhang et al., 2022).

Fig. 4 shows the study arms by year and technology and the studies by setting.

Of the 56 arms, 36 modelled incineration (grate, fluidised bed, rotary kiln, integrated or solar-assisted), 15 modelled gasification, plasma, pyrolysis or their hybrids, and 5 modelled other configurations (MSW–natural-gas hybrids, coal co-firing, a bottoming cycle and a multi-route scenario model). Net output ranged from about 0.01 MWe in micro-polygeneration models to 111 MWe. Fig. 5 maps the evidence by technology and outcome.

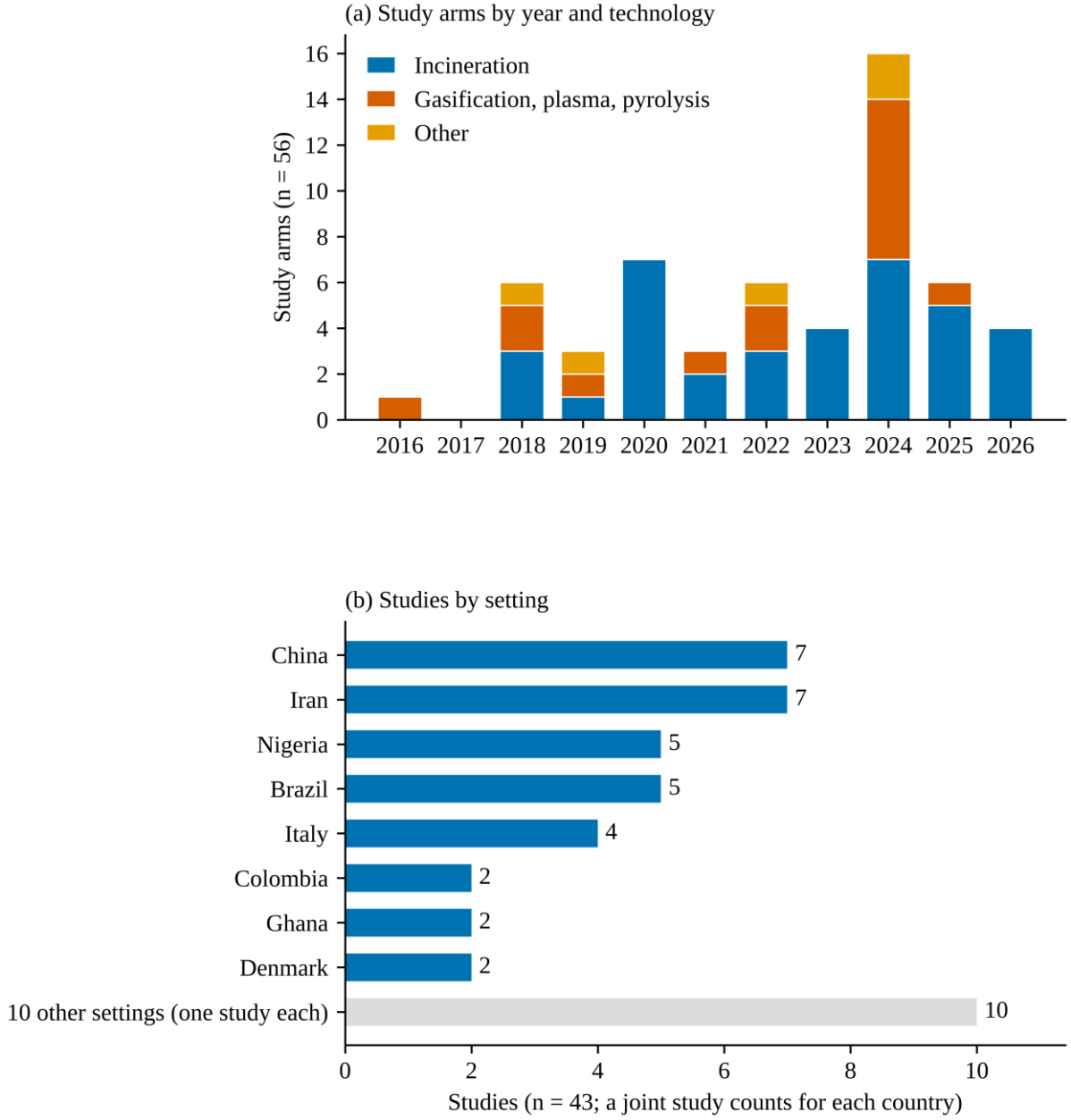


Fig. 4 Study arms by year and technology (a) and studies by setting (b). A study set in two countries is counted for each; the Iran–Italy study therefore appears in both bars.

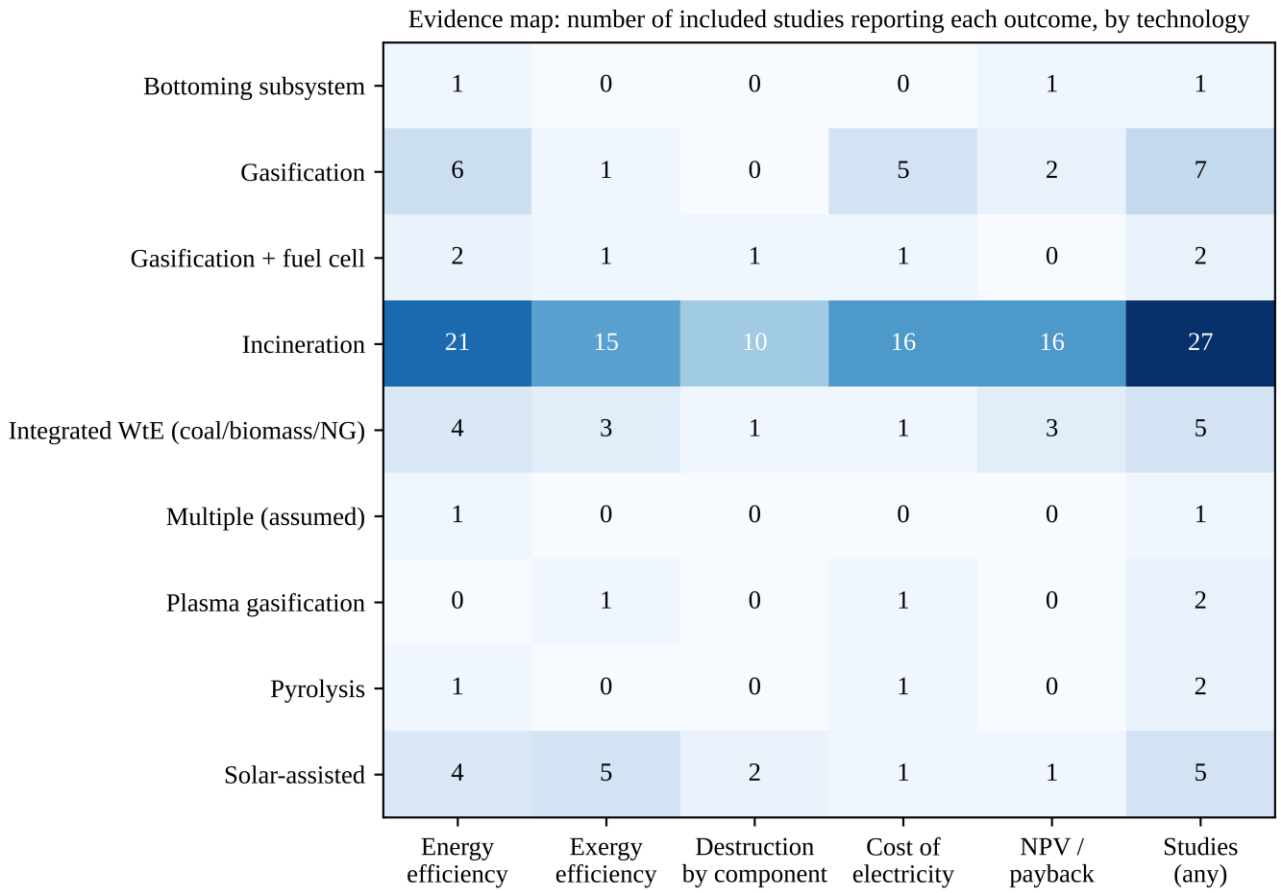


Fig. 5 Evidence map: number of study arms reporting each outcome, by technology group.

4.3 Appraisal

The appraisal results are shown in Fig. 6 and Supplementary File S6.

- **Objectives (D01)** were clear in 39 studies.
- **Validation (D10)** was Adequate in 3 studies and Inadequate in 27.
- **Balance closure (D04)** was Adequate in 2 studies (Pan et al., 2020; Zhang et al., 2022) and Inadequate in 14, where the reported flows did not close or contradicted each other.
- **Economic assumptions (D09)** were Inadequate in 13 studies. Price year, O&M basis or discounting were missing or inconsistent.
- **Auxiliary loads (D08)** were Inadequate in 12 studies.
- **Reproducibility (D12)** was Adequate in no study (Partial 33, Inadequate 10). No study published its model files.
- **Sensitivity analysis (D11)** was Partial in 38 studies: usually one-at-a-time, with no uncertainty propagation.

The reviewer's recalculations found internal inconsistencies in many studies. Examples:

- A component table in which a turbine destroys more exergy than the combustion chamber the text identifies as largest (Vilardi & Verdone, 2020).
- An LCOE above the electricity tariff while the NPV is positive (Barrak, Melian Cobas, Renó, & Rúa Orozco, 2026; Yakah et al., 2024).
- LCOEs of 0.83 and 2.3 USD/MWh, which are implausibly low (Rimon, Mohtasim, Kibria, Ahmed, & Das, 2025; Sechoala, Popoola, & Ayodele, 2023).
- An LCOE whose unit is not printed (Escamilla-García et al., 2023).
- An exergy efficiency of 26% that cannot follow from the reported total exergy destruction, which is about 0.02% of the fuel exergy (Balmant et al., 2019).

These values are flagged in the matrix and kept out of the summary ranges.

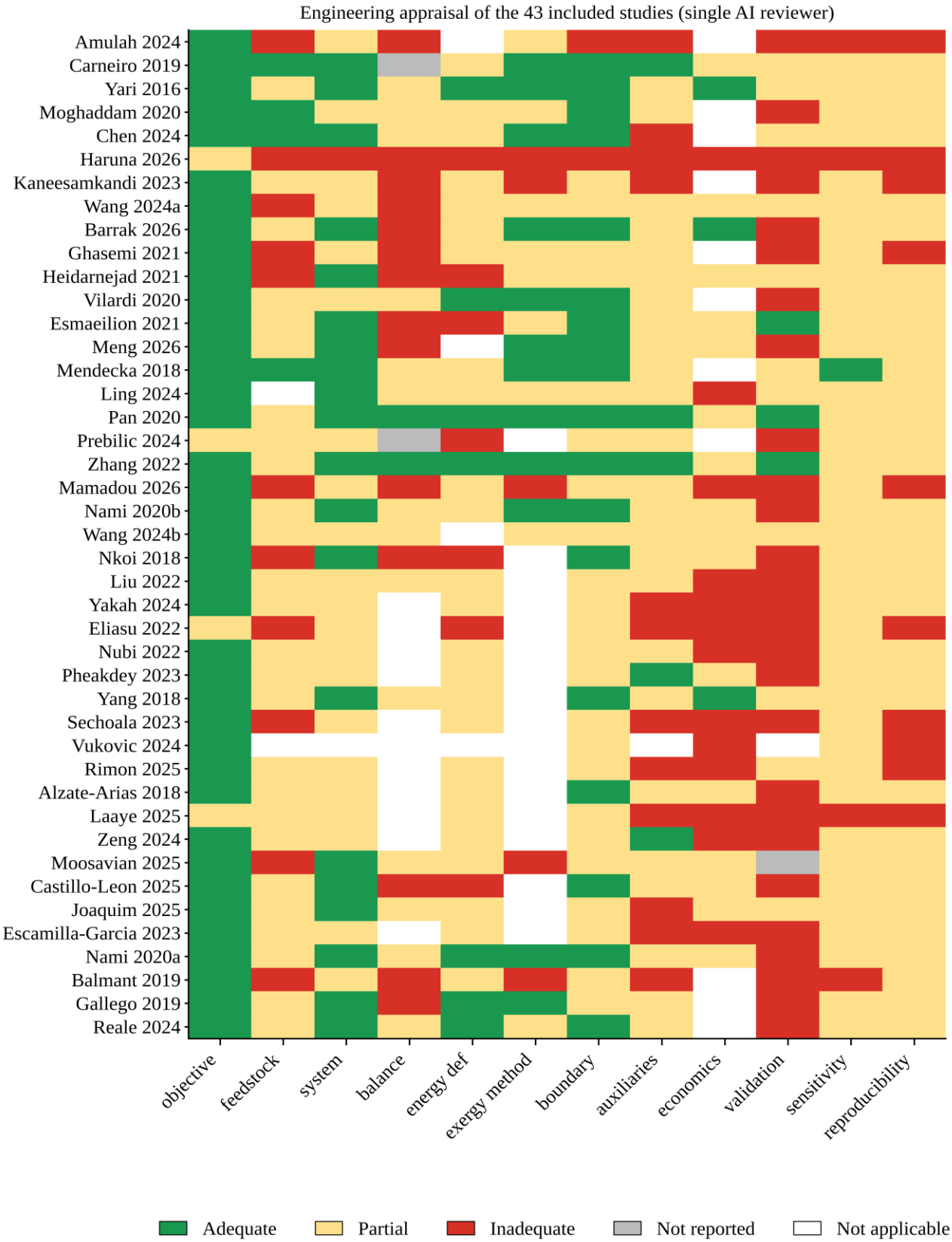


Fig. 6 Twelve-domain engineering appraisal of the 43 included studies (A = adequate, P = partial, I = inadequate, NR = not reported, NA = not applicable).

Fig. 7 gives the rating counts for each domain: the objective was clear in 39 studies, whereas validation was inadequate in 27 and reproducibility was adequate in none.

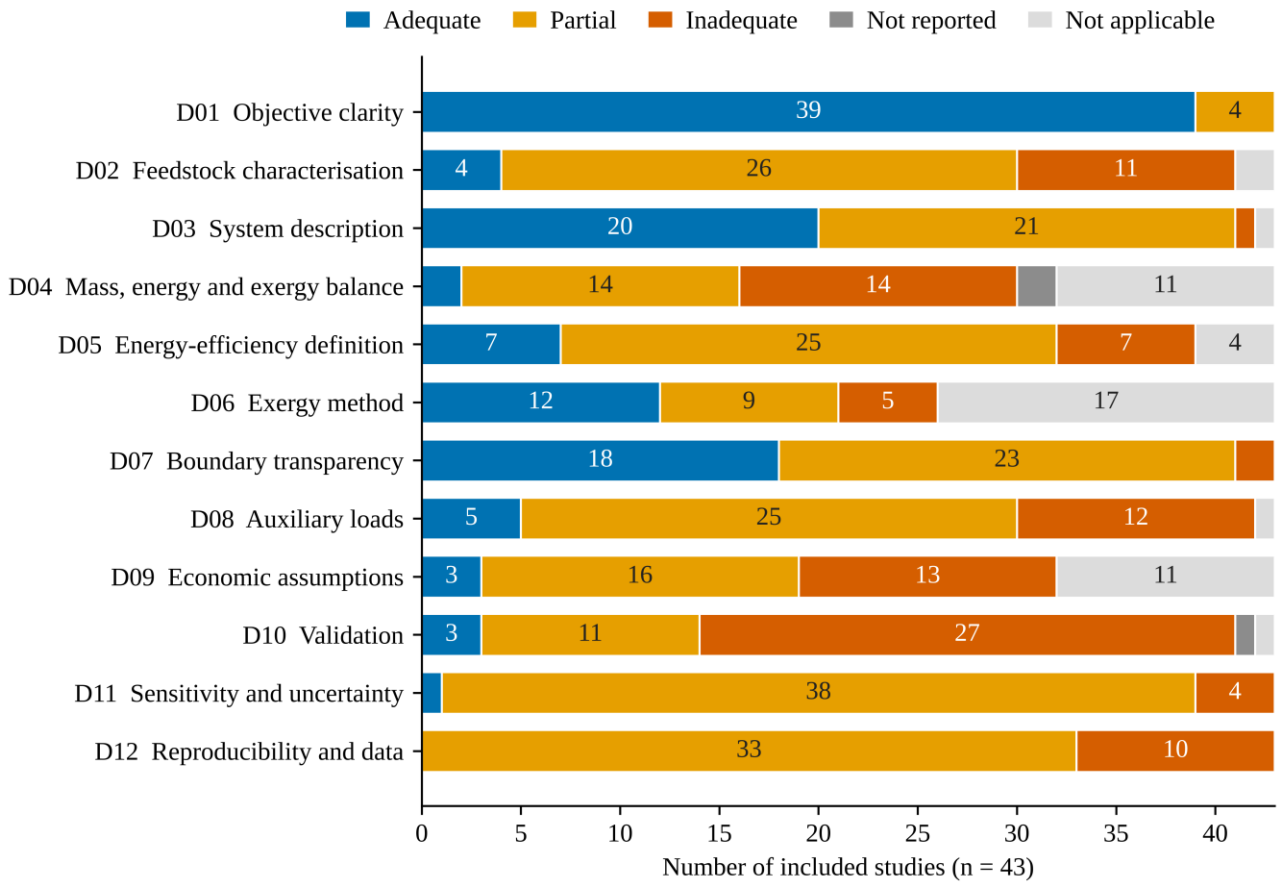


Fig. 7 Appraisal ratings by domain for the 43 included studies (number of studies per rating).

4.4 RQ1 and RQ6: electrical efficiency and its definitions

Forty-two rows in Supplementary File S7 report or assume an electrical or energy efficiency, and they use at least eight different definitions.

Explicitly defined net efficiencies. Only the two F-NCEPU studies define net electrical efficiency explicitly as net WtE power divided by LHV input (Pan et al., 2020; Zhang et al., 2022). For the same 500 t/d standalone plant they report 20.49% and 19.73%.

Other definitions in use:

- the product of boiler and conversion efficiency (21.7–23.7%; Vilardi & Verdone, 2020)
- power divided by boiler heat rather than fuel input (17.3%; Nkoi, Koate, & Hart, 2018)
- an undefined "plant" or "thermal" efficiency (Castillo-Leon, Tarazona-Romero, Ascanio-Villabona, & Lenguerke-Perez, 2025; Esmaeilion et al., 2021)
- first-law efficiencies of multigeneration systems that add heat, cold or water to the numerator (47.9–85.3%)

Assumed rather than calculated. In 10 studies (12 rows), mostly economic models, the electrical efficiency was an input assumption of 19.2–32% rather than a calculated result. In two of these, the reviewer's recalculation from reported power and fuel input gave a different value: 16.5% against the stated 22.6% (Castillo-Leon et al., 2025), and 48.1% against the stated 34.42% (Esmaeilion et al., 2021).

LHV versus HHV basis. One study shows how the basis changes the result (W05). The efficiency penalty of co-firing MSW in a 660 MW coal unit was −1.55 percentage points on an LHV basis but −4.22 points on an HHV basis (Liu et al., 2022).

Because definitions differ, no pooled electrical efficiency is reported (gate G05: NOT DIRECTLY comparable).

4.5 RQ2: exergy efficiency and exergy destruction

The exergy efficiencies by definition class are given in Table 2 and Fig. 8.

Table 2 Exergy efficiency by definition class (from Supplementary File S7).

Class	Technology	Arms	Studies (independent)	Range, %	Median, arms / independent groups, %
EX-P (power / fuel chemical exergy)	incineration	8	6 (5)	15.39–34.4	24.8 / 30.9
EX-P	gasifier + SOFC	1	1 (1)	18.01	—
EX-PH (heat/cold exergy counted)	incineration	5	4 (3)	13.27–35.34	26.7 / 26.2
EX-PS (solar, gas or biogas input added)	incineration	4	3 (3)	11.4–24.0	21.4 / 21.4
EX-PS	gasification	3	3 (3)	14.3–52	27.5 / 27.5
EX-UNC (definition unclear or not reproducible)	incineration	3	3 (3)	3.56–26	25.0 / 25.0
EX-CITY (city-scale annual totals)	incineration / plasma	2	1 (1)	5.05; 9.22	—
EX-PHYS (physical exergy only)	incineration (fluidised bed)	1	1 (1)	79–97	—

Power-only incineration (EX-P). Only this class is conditionally comparable across studies (gate G01). Its six studies are Vilardi and Verdone (2020), Esmaeilion et al. (2021), Pan et al. (2020), Zhang et al. (2022), Barrak et al. (2026) and Meng (2026).

They share the indicator definition but differ in:

- the fuel chemical-exergy method: specific exergy, ψ×LHV, H/C–O/C correlations, standard chemical exergies, or waste-specific correlations
- the boundary: support fuel included in Barrak et al. (2026); flue-gas treatment included in Meng (2026); integration with an adjacent plant in the F-NCEPU studies

Their range (15.4–34.4%) is therefore a description of reported values, not an estimate of a population mean. The median is unstable: 24.8% when every arm counts once, and 30.9% when each independent group counts once, because the F-NCEPU family contributes four lower arms.

Sensitivity analyses.

- Excluding studies rated Inadequate on balance closure leaves 18.7–34.4% from 2 independent groups.
- All EX-P values were verified in full text.

The other classes. Values from the other classes are reported side by side and never pooled:

- City-scale exergy efficiencies of 5.05% (incineration) and 9.22% (plasma) come from one study that used annual city waste exergy as the input (Amulah, Oumarou, & Muhammad, 2024).
- Physical-exergy-only values of 79–97% exclude the fuel's chemical exergy (Kaneesamkandi & Sayeed, 2023).

Neither describes plant performance in the usual sense. Two further studies reported exergy efficiencies only for a waste-heat-recovery subsystem (Ling & Chen, 2024; Reale & Massoli, 2024) and are not included in Table 2.

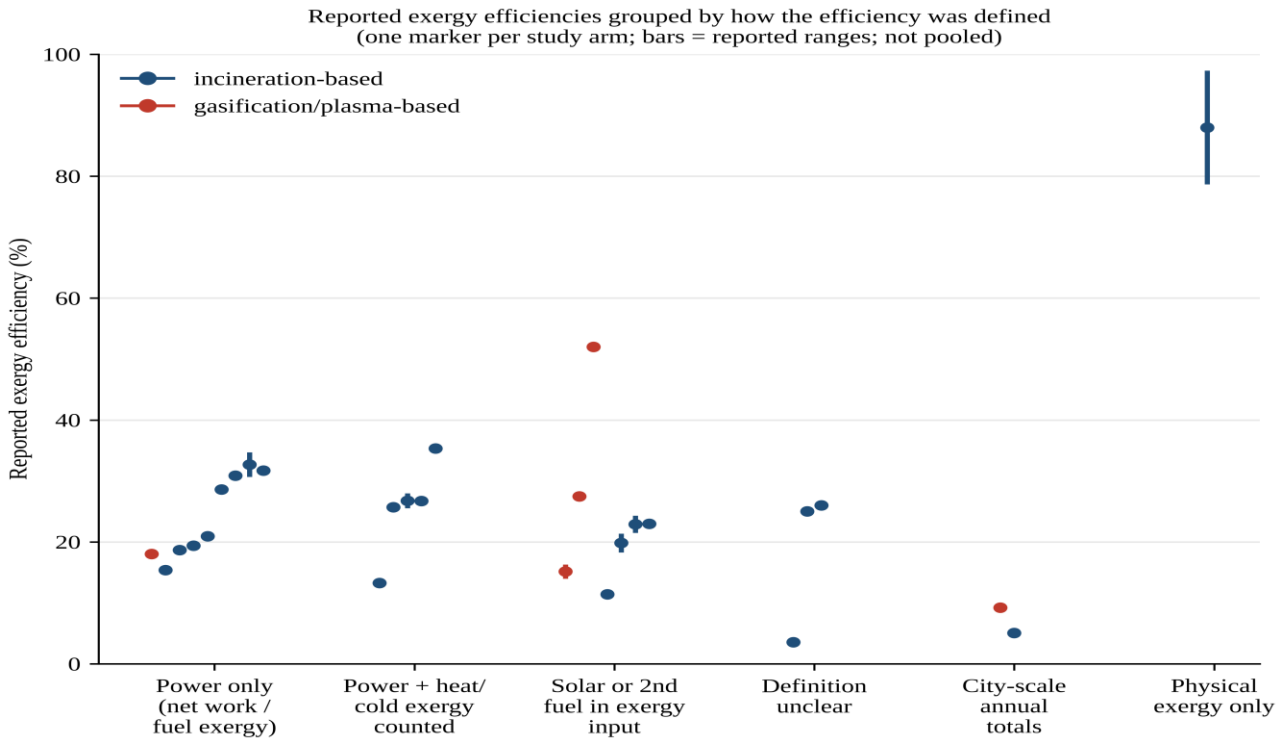


Fig. 8 Reported exergy efficiencies grouped by definition class. Each point is one study arm; only EX-P values are conditionally comparable.

Exergy destruction (Table 3, Figs. 3 and 9). Twelve studies (10 independent groups) reported which component destroys most exergy, and in every one it was the combustion or conversion stage: the furnace, incinerator, combustion chamber, WtE boiler or gasifier. Its share of total destruction ranged from 39.6% to 91%.

The upper part of this range comes from boundaries that combine the furnace and boiler. In Meng (2026), for example, the incinerator alone accounts for 39.6%, but 69.5% when the boiler is included. The one gasifier-based value was 47% (Ghasemi, Shayesteh, Doustgani, & Pazoki, 2021).

The direction of this finding is consistent across studies (gate G06, CONDITIONALLY comparable). Its magnitude depends on where the component boundary is drawn.

Table 3 Largest exergy destruction component (from Supplementary File S7).

Study	Configuration	Component	Share of total destruction, %
Moghaddam & Ghasemi (2020)	incineration	furnace	83
Haruna et al. (2026)	incineration	incinerator	91
Barrak et al. (2026)	incineration	combustion	59
Ghasemi et al. (2021)	gasification polygeneration	gasifier	47
Vilardi & Verdone (2020)	incineration	combustion chamber	52 (RC)
Esmaeilion et al. (2021)	incineration	incinerator	66
Meng (2026)	incineration	incinerator (with boiler)	39.6 (69.5)
Mendecka et al. (2018)	solar-assisted incineration	WtE boiler	64
Pan et al. (2020)	separate / integrated	boilers	81 (RC)
Mamadou et al. (2026)	CCHP	incinerator	62.5
Nami et al. (2020b)	CHP / CHP-ORC	incinerator	86.2 / 86
Nami et al. (2020a)	trigeneration	incinerator	89.5

RC = recalculated by the reviewer from the published component table.

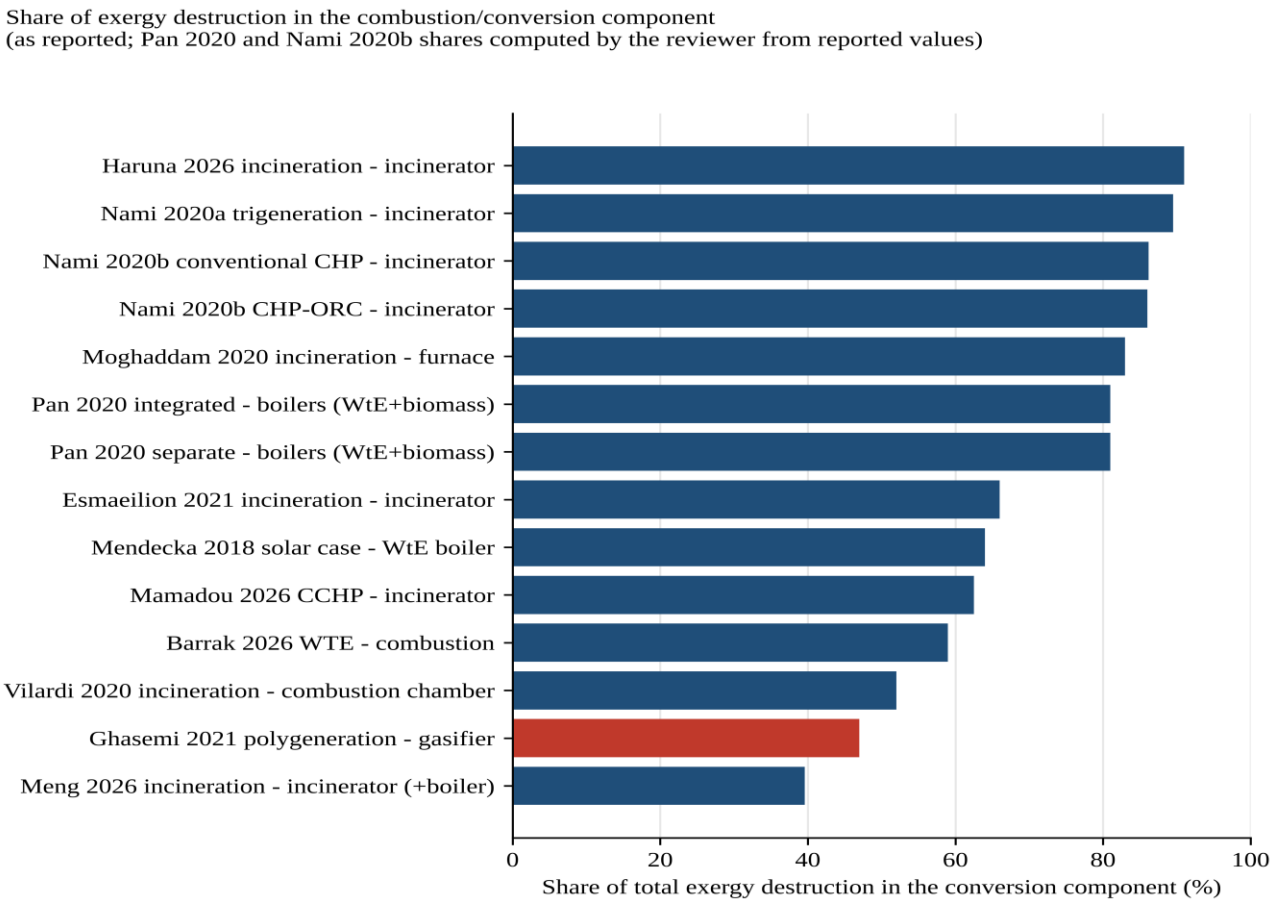


Fig. 9 Share of total exergy destruction in the combustion or conversion component, by study.

4.6 RQ3: thermoeconomic indicators

The 30 cost results fall into five definitions (Table 4, Fig. 10). Three results were flagged as implausible or of unverified unit and excluded from the summaries: the LCOEs of 2.3 and 0.83 USD/MWh, and an LCOE whose unit is not printed (216.92).

Table 4 Cost of electricity by definition (USD/MWh as published; nominal; outliers excluded; from Supplementary File S7).

Definition	Results	Studies (independent)	Range	Median, results / independent groups	Price year stated
Model LCOE (discounted or as stated)	10	9 (9)	44–200	88.5 / 100	2
LCOE with incentives	3	2 (2)	38.7–175.2	58.2 / 111.8	0
LCOE of hybrid or microgrid system	2	2 (2)	179.2–527.7	—	0
Exergoeconomic unit cost of electricity	6	5 (4)	11.3–88.9	68.3 / 67.2	1
Undiscounted operating-plant cost	6	1 (1)	135–479	385 / 340	0

Three studies reported a cost range rather than a single value and enter Table 4 at the midpoint of that range: Haruna, Muhammad, and Abdulrahman (2026), 150–250 USD/MWh; Nubi, Morse, and Murphy (2022), 46–62 USD/MWh for incineration; and Zeng et al. (2024), 36–51 USD/MWh. Counting the ends of these ranges, model LCOEs span 36–250 USD/MWh.

The inputs to these costs varied widely:

- Discount rates ranged from 3.5% to 12.5%, and lifetimes from 10 to 25 years.
- In most model-LCOE studies the plant efficiency was assumed (Section 4.4), so the LCOE does not reflect a calculated thermodynamic result.
- Exergoeconomic unit costs often set the waste fuel cost at or near zero. Nami et al. (2020a) report 11.29 USD/MWh with zero fuel cost, so these are not costs of electricity in the LCOE sense (gate G08).
- The operating-plant costs of Vuković and Makogon (2024) are undiscounted and exclude gate fees, so they cannot validate the model LCOEs (gate G09).

Cross-study cost levels are therefore NOT DIRECTLY comparable (G07), and the ranges are reported only to show how wide and definition-dependent they are.

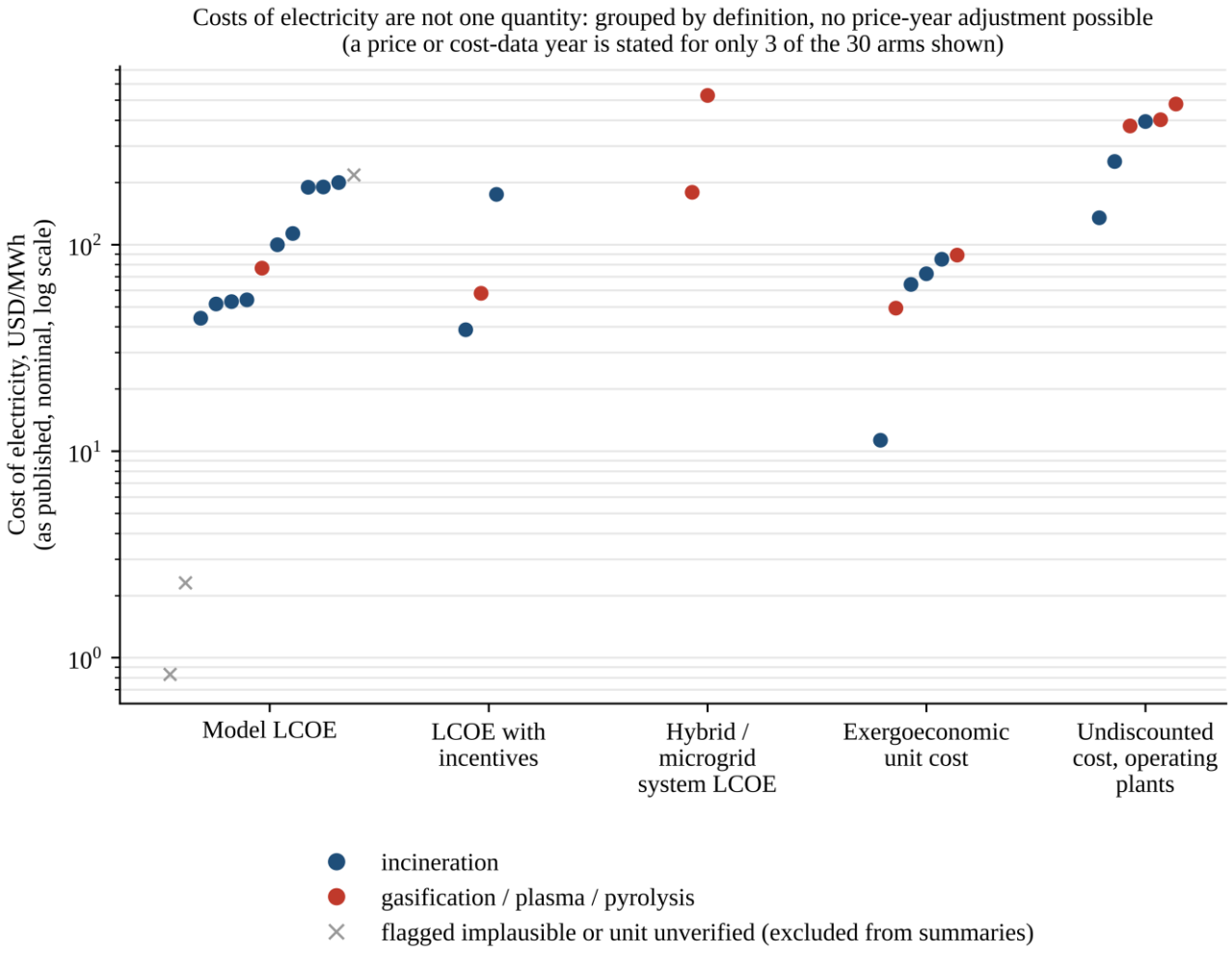


Fig. 10 Reported costs of electricity grouped by definition (log scale). Crosses mark flagged values excluded from summaries.

Fig. 11 brings the exergy-efficiency and cost summaries together with the sensitivity analysis. It describes ranges and medians only and is not a pooled estimate.

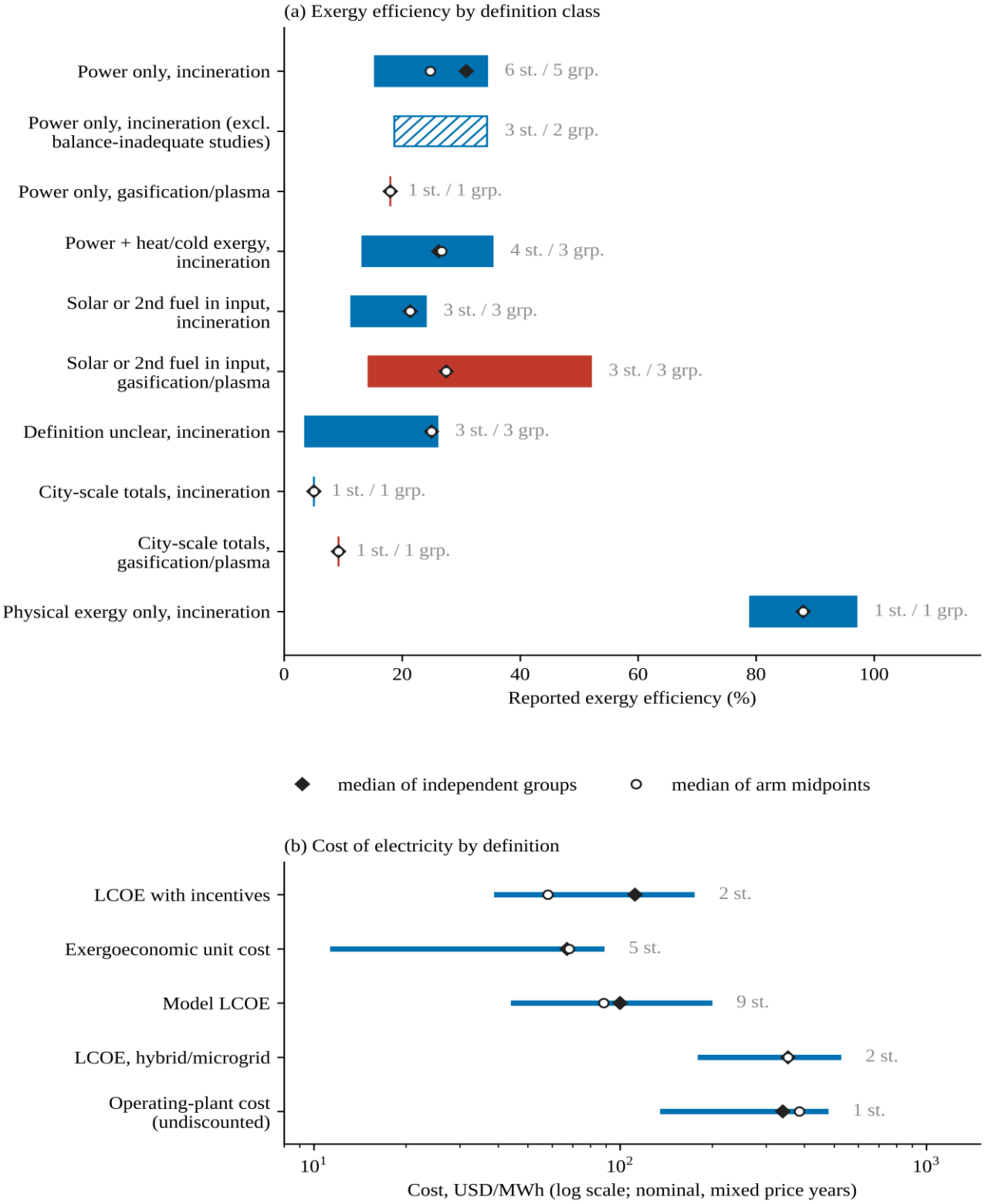


Fig. 11 Summary statistics by definition class. (a) Exergy efficiency: bars show reported ranges; diamonds, median of independent groups; circles, median of arm midpoints; the hatched bar repeats the power-only incineration range after excluding studies rated Inadequate for balance closure (st. = studies, grp. = independent groups). (b) Cost of electricity by definition on a log scale; values are nominal and most price years were not stated. Classes are not comparable with one another.

4.7 RQ4 and RQ5: within-study evidence on feedstock and technology

Because cross-study comparison was blocked by the gate, effects of feedstock and technology were taken from studies that varied one factor within one model (Table 5; full list in Supplementary File S7).

Table 5 Within-study direction of effects (selected; FT-verified unless marked).

ID	Study	Change	Indicator	Effect as reported
W01	Chen et al. (2024)	gasifier-inlet moisture 40% → 0% by heat-pump drying	net power	34.47 → 42.97 MW
W03	Escamilla-García et al. (2023)	LHV −25/−50/−75%	NPV	706.4 → 410.7 / 174.9 / −86.4 MUSD
W04	Liu et al. (2022)	pre-drying MSW co-fired at 30% mass	plant efficiency	+1.24 to +2.26 points (HHV)
W06	Nubi et al. (2022)	incineration vs gasification, same cost model	LCOE	46–62 vs 77 USD/MWh
W07	Alzate-Arias et al. (2018)	incineration vs gasification, same plant size	LCOE (incentive case)	38.73 vs 58.17 USD/MWh
W08	Vuković & Makogon (2024)	six technologies, operating plants	undiscounted cost	rotary kiln 135 and grate 253 lowest; plasma 479 highest (USD/MWh)
W11	Pan et al. (2020)	standalone vs integrated with biomass plant	net el. / exergy efficiency	20.49 → 22.12% / 19.40 → 20.94%
W12	Zhang et al. (2022)	standalone vs steam integration with coal unit	net el. / exergy efficiency	19.73 → 30.21% / 18.68 → 28.60%
W14–15	Mendecka et al. (2018)	solar vs gas superheater	exergy efficiency; exergy cost vs thermo-ecological cost	gas higher efficiency (21.8–24.0 vs 18.6–21.1%); ranking reverses between the two cost indicators
W16	Nami et al. (2020b)	turbine inlet 500 → 600 °C	electrical / exergy efficiency	25.87 → 26.9% / 27.24 → 28.06%
W18	Yang et al. (2018)	availability −20% / capital −20% / gate fee +20%	LCOE	+64.2% / −42.9% / −34.0%
W21	Vilardi & Verdone (2020)	flue-gas recirculation	net / exergy efficiency	21.7 → 23.5%; 0.31 → 0.34
W22	Moosavian et al. (2025) (PARTIAL)	power only vs power + desalinated water	exergy efficiency	25% vs 16%

Feedstock (RQ4). Lower moisture and higher heating value consistently improved power output, efficiency or NPV (W01–W04). No study isolated the effect of waste composition other than moisture and LHV.

Technology (RQ5).

- **Incineration versus gasification:** in both studies that compared them under the same economic assumptions, incineration had the lower LCOE (W06, W07). Both relied on assumed rather than calculated efficiencies.
- **Operating-plant costs:** grate and rotary-kiln plants had lower average costs than gasification, plasma and pyrolysis plants (W08). That comparison is between different plants in different countries.
- **Integration with a coal or biomass plant** raised the WtE exergy efficiency in both F-NCEPU studies (W11–W12). However, the larger gain in Zhang et al. (2022) attributes part of the coal unit's high-efficiency steam cycle to the WtE plant.

- **Indicator choice can reverse a ranking:** Mendecka, Lombardi, Gładysz, and Stanek (2018) found that a solar superheater looks worse on exergy cost but better on thermo-ecological cost (W15).

Fig. 12 plots the size of the within-study changes in Supplementary File S7, so that the direction and the order of magnitude of each single-factor effect can be seen at a glance. Bar lengths from different studies should not be compared with each other, because plant models, bases and cost assumptions differ.

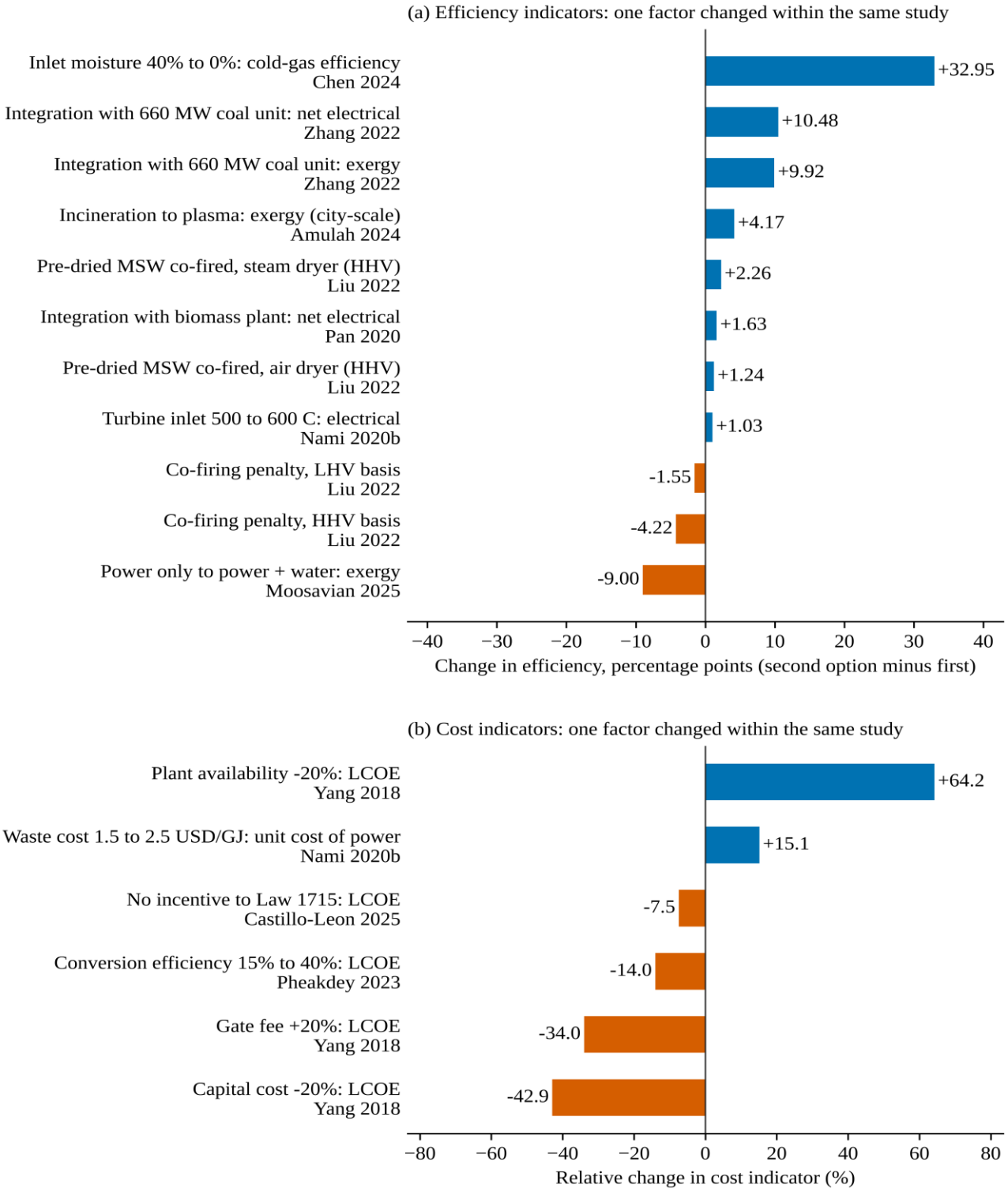


Fig. 12 Within-study effects of changing one factor (Supplementary File S7, W01–W22 except W10). (a) Change in efficiency indicators, in percentage points (second option minus first). (b) Relative change in cost indicators. Bar labels give the source study.

4.8 Confidence in the main findings

The criteria used in Table 6 are:

- **Moderate:** a consistent direction in at least 3 independent groups, full-text verified, with comparison at least CONDITIONALLY allowed.
- **Low:** a range from a CONDITIONALLY comparable set, or a direction from 1–2 groups.
- **Very low:** values that are NOT DIRECTLY comparable, or a single study with flagged inconsistencies.

These are the reviewer's judgements and not a formal GRADE assessment.

Table 6 Summary of findings and confidence.

Finding	Evidence	Confidence
Combustion or conversion is the largest source of exergy destruction	12 studies, 10 groups, all consistent	Moderate (magnitude: Low)
Power-only incineration exergy efficiency lies in 15–34%	6 studies, 5 groups, conditionally comparable	Low
Drying the feed or a higher LHV raises output, efficiency or NPV	3 studies, 3 groups, within-study	Moderate
Steam-cycle upgrades (higher temperature, FGR, integration) raise efficiency	4 studies, 3 groups, within-study	Moderate
Incineration has a lower modelled LCOE than gasification	2 studies, assumed efficiencies	Low
Typical LCOE of MSW-to-electricity	9 studies, not comparable	Very low (no estimate offered)
Reporting and validation are weak	43 studies appraised	Moderate (single reviewer)

5. DISCUSSION

5.1 Principal findings

Three findings stand out:

1. **A headline number usually hides a choice of definition.** Within a single label such as "exergy efficiency" or "LCOE", reported values span more than an order of magnitude because the indicators are defined differently. When the values are grouped by definition, the spread narrows. Power-only incineration, for example, falls within 15–34% exergy efficiency.
2. **The most reliable results are directional.** Combustion irreversibility dominates the exergy destruction. Removing moisture, recirculating flue gas, raising steam temperature and integrating with a more efficient steam cycle all improve performance.
3. **Economic results are weakly tied to thermodynamics.** Most cost models assume an efficiency rather than calculate one, and almost none state a price year. As a result, the reported LCOE cannot be traced to a thermodynamic design or adjusted to a common basis.

5.2 Interpretation

Exergy destruction. The dominance of combustion is expected from thermodynamics: the irreversibility of burning a low-grade, wet fuel at limited steam conditions. The variation in its magnitude (40–91%) mainly reflects where authors draw the boiler boundary. Reporting destruction for the furnace and the heat-transfer surfaces separately would make these values comparable.

Exergy efficiency. The EX-P range overlaps the annual net electrical efficiencies of six operating Italian WtE plants (14.5–27.3%) reported in a study excluded from the synthesis because its outcome was whole-chain costing (Rigamonti, Borghi, Martignon, Ciceri, & Grosso, 2019); these are used here as context only.

This is consistent with fuel chemical exergy being only slightly higher than LHV for MSW. The ratio of chemical exergy to LHV (β) was about 1.1 in the unpublished manuscript of Appendix B, for example.

Feedstock effects. The fuel chemical-exergy method was rarely justified. With β varying by a few percent between methods, exergy efficiencies can shift by about 1 percentage point; in the unpublished manuscript of Appendix B, recalculating with a Szargut-type β changed the value by −0.27 points. This is small compared with definitional differences, but it is not negligible for rankings.

Technology choice. The within-study evidence favours incineration over gasification on modelled cost, and grate or rotary kiln over plasma and pyrolysis on operating-plant cost. These comparisons are few, and the modelled ones depend on assumed efficiencies. Exergy-based comparisons of incineration and gasification under the same boundary and feed were not found in the open-access evidence.

5.3 Comparison with existing reviews

Fourteen reviews were mapped on fifteen descriptive fields, including review type, technologies, outcomes, method, uncertainty, boundary and quality treatment (Supplementary File S11). Three findings shape how this review's contribution should be read.

The exergy ranges confirm an earlier review. The abstract of Soltanian et al. (2022) reports exergy efficiencies of about 17–40% for incineration-based and 22–56% for gasification-based MSW systems. The EX-P incineration range here (15.39–34.4%) and the EX-PS gasification range (14.3–52%) are consistent with those figures. The ranges themselves are therefore not a new result.

Systematic methods and comparability framing are not new either. Inuwa et al. (2026) and Rumbayan et al. (2026) used PRISMA-based searches of MSW thermochemical and WtE techno-economic literature. Banaś et al. (2026) graded MSW-incineration findings as robust, mixed or non-comparable and declined to pool them. The remaining mapped reviews address technology evolution, sustainability overviews, decision frameworks, efficiency enhancement or qualitative technology comparison (Alrbai et al., 2026; Hsu et al., 2024; Jamilatun, Pitoyo, & Setyawan, 2023; Katruksa, Pongpakpian, & Kerdlap, 2026; Makarichi, Jutidamrongphan, & Techato, 2018). Of these, Makarichi and Hsu could be judged from title and record only; the abstract of Katruksa et al. (2026) describes efficiency-enhancement strategies (combustion control, heat recovery, hybrid and grid integration) without a synthesis of indicator values. A review titled as a systematic evaluation of the efficiency of WtE incineration for electricity (Maphuhla & Oyedeji, 2025) was identified only from the reference list of Katruksa et al. (2026) and could not be inspected; it is the review most likely to overlap with RQ1.

What this review adds, in the content inspected, is the combination applied to MSW-to-electricity exergy and cost indicators:

1. grouping exergy-efficiency and cost results into definition classes before any comparison, with an explicit comparability gate
2. reviewer recalculation of reported balances, which changed two stated efficiencies (Section 4.4)
3. a 12-domain engineering appraisal of each study
4. independence-aware counting through study families, with open logs and scripts

The contribution is therefore best described as potentially distinct, with limitations. The full text of the closest review was not read, so it may already separate exergy definitions. Four reviews, including Maphuhla and Oyedeji (2025), were judged from title and record only, and subscription databases were not searched for reviews. Reading the full texts listed in Supplementary File S11 would settle the overlap.

5.4 Strengths and limitations

Strengths:

- a protocol written before screening
- complete logging of searches, decisions and scripts
- extraction that preserves definitions
- independence-aware counting through study families
- no pooling of non-comparable values

Limitations. The following limitations affect how far the results can be relied on:

1. **No subscription databases.** Scopus, Web of Science and Compendex were not searched, so recall is unknown.
2. **Open-access full texts only.** 349 of 420 reports sought could not be assessed at all, mostly Elsevier journals (*Energy*, *Energy Conversion and Management*, *Applied Thermal Engineering*, *Waste Management*), where much of the exergoeconomic literature is published. The included evidence over-represents open-access outlets (MDPI journals, regional journals, conference proceedings), and this may bias it towards smaller or less-reviewed studies.
3. **Single reviewer.** Screening, extraction and appraisal were done by one reviewer, an AI agent (Section 2.11), without dual independent checking or verification by a second person. Errors in reading tables or in judging eligibility are possible; the borderline items are listed in Supplementary File S12.
4. **Title-only screening.** Most records were screened on title alone (DV06). The many "unclear" records reduced the risk of wrong exclusion but raised the number of reports that could not be retrieved.
5. **Models, not plants.** Almost all evidence comes from models. Only 3 were adequately validated, so the ranges describe modelled rather than measured performance.
6. **Copyright limits on quotation.** The retrieval tool paraphrases text, so values were transcribed from tables as read. Each value has its location recorded for checking.
7. **No registered protocol.** The protocol was not registered, and it was written after a pilot search (DV01).
8. **Search terms.** The audit found that the term "exergetic" had been missed; the added query (Q7) found 3 more eligible studies. Other synonyms, such as "second-law" or "availability analysis", were not tested, so further studies may have been missed. As an informal recall check, 10 of 13 primary MSW-to-electricity studies cited by one recent review (Katruksa et al., 2026) were already in the records. One of the three missed, an NPV-based techno-economic study (Asante, Gyamfi, & Amo-Boateng, 2023), was missed because the queries had no NPV or payback terms (Supplementary File S11).
9. **Incomplete review mapping.** The closest existing review was judged from its abstract, four others from title and record only, and one review query was rate-limited (DV17). Overlap with existing reviews may therefore be understated.

5.5 Implications and research priorities (RQ8)

For authors of primary studies. A minimum reporting set would make cross-study synthesis possible:

1. Exergy efficiency definition, stating products and fuels, with the equation.
2. Fuel chemical-exergy method and β value.
3. LHV or HHV basis, and moisture basis.
4. Gross and net output, with an itemised auxiliary load.
5. Component boundaries for the destruction breakdown, with furnace and boiler separate.
6. A closed mass, energy and exergy balance table, including stack and ash losses.
7. For costs: currency, price year, discount rate (real or nominal), lifetime, capacity factor, O&M, gate fee and revenue treatment, and whether efficiency was calculated or assumed.
8. Validation against plant or design data.
9. Model files or full input tables.

Research priorities:

- operating-plant exergy and cost studies
- same-boundary comparisons of incineration and gasification
- uncertainty propagation in place of one-at-a-time sensitivity
- a repeat of this review with subscription-database access and full texts of the paywalled literature

6. CONCLUSION

From 43 open-access studies, the evidence supports directional conclusions:

- Combustion is the main source of exergy destruction in MSW-to-electricity systems.
- Drying, flue-gas recirculation, higher steam temperature and integration with efficient steam cycles raise efficiency.
- Within the few studies that compare them, incineration has lower modelled cost than gasification.

Power-only incineration exergy efficiency lies between about 15% and 34% under a broadly shared definition.

The evidence does not support a single typical value for exergy efficiency across definitions, or for the cost of electricity. These indicators should not be compared across studies unless their definitions, bases and price years are reported.

ACKNOWLEDGMENT

During the preparation of this study, the author used Claude (Anthropic), an AI agent, to run the database searches through open APIs, screen records, read open-access full texts, extract data, appraise studies, write the analysis code, draw the figures and draft the text, as described in Section 2.11. The author reviewed and edited the output and takes full responsibility for the content of this publication.

Author contributions: Conceptualization, A.A.E.; methodology, A.A.E.; writing—review and editing, A.A.E.; supervision, A.A.E.; project administration, A.A.E. The literature search, screening, data extraction, analysis and first draft were carried out by an AI agent (Claude, Anthropic) under the author's direction, as described in Section 2.11. The author has read and agreed to the published version of the manuscript.

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Conflicts of interest: The author declares no conflicts of interest.

Informed consent: Not applicable.

Data availability: All data supporting this review are provided in Supplementary Files S1–S13: search logs and raw result pages, screening decisions, full-text notes, the extraction matrix, appraisal tables, synthesis tables, the analysis code that regenerates every table, figure and PRISMA count, and the quality-control files.

Supplementary materials: File S1: Search log, exact query strings, dates, counts, API URLs and raw result pages; File S2: Deduplication log, unique records, title/abstract screening decisions and PRISMA record status; File S3: Report retrieval log, per-study full-text notes with source locations, and the list of reports not retrieved; File S4: Extraction matrix (56 study arms, 33 fields) with verification status and flags; File S5: Abstract-tier records; File S6: Twelve-domain appraisal with reasons, and domain counts; File S7: Synthesis tables S1–S7 (exergy by class, destruction shares, efficiency definitions, cost summaries, within-study effects W01–W22 except W10, comparability gate G01–G11) and the meta-analysis feasibility note; File S8: Python code that regenerates every table, figure and PRISMA count; File S9: Recalculation of the unpublished candidate manuscript (Appendix B); File S10: Protocol v1.0, capability audit and deviation log (DV01–DV17); File S11: Existing-review mapping: review searches, content inspection, novelty matrix and rating rationale; File S12: Quality control: claim-to-evidence matrix, unit-conversion check, issue log, internal audits and human-verification checklist; File S13: PRISMA 2020 checklist.

Abbreviations: CCHP, combined cooling, heating and power; CHP, combined heat and power; FGR, flue-gas recirculation; HHV / LHV, higher / lower heating value; HRSG, heat-recovery steam generator; LCOE, levelised cost of electricity; MSW, municipal solid waste; NPV, net present value; NR / NA / NC, not reported / not applicable / not calculable; O&M, operation and maintenance; ORC, organic Rankine cycle; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses; RDF / SRF, refuse-derived fuel / solid recovered fuel; RQ, research question; SOFC, solid oxide fuel cell; WtE, waste-to-energy.

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