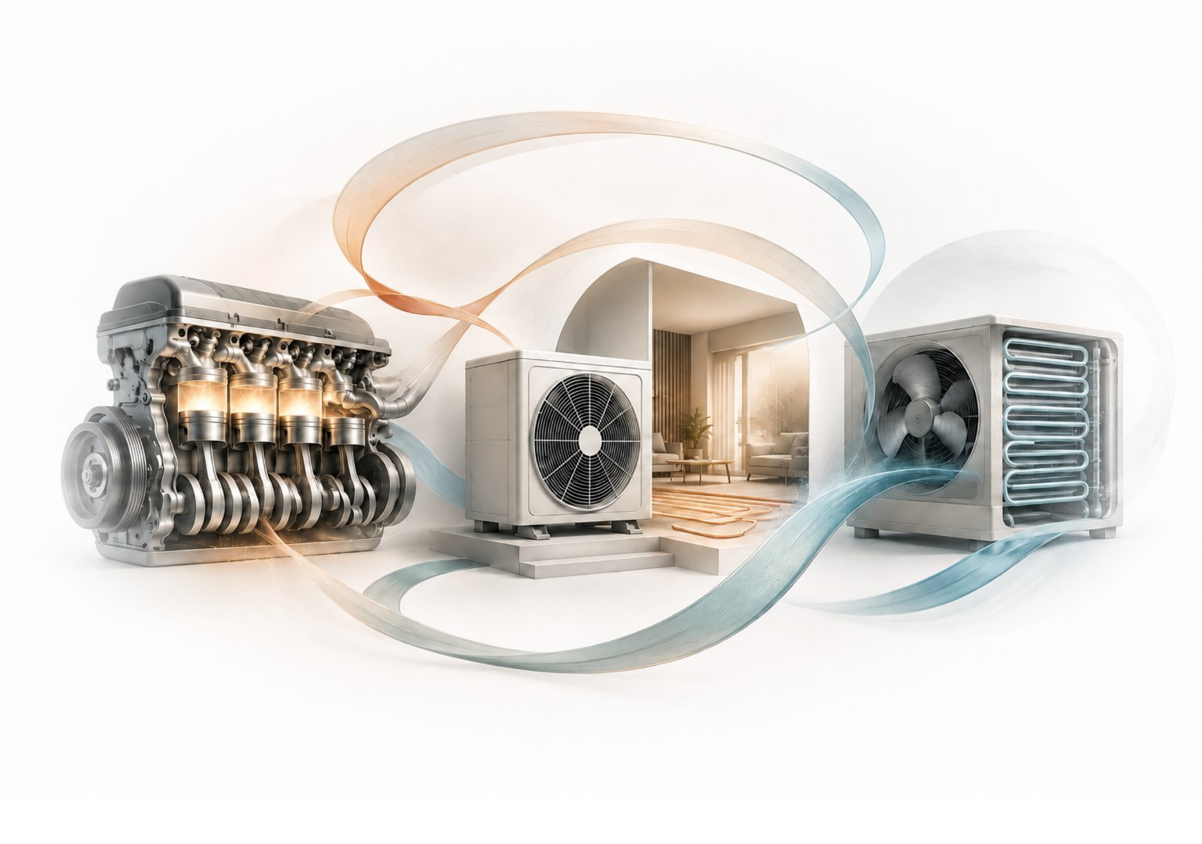
THERMODYNAMICS PUBLICATION PROGRAMME

Extending the Foundations of Thermodynamic Heat–Work Conversion in Cycles

PUBLIC OVERVIEW

A New Way to Compare—and Improve—Engines, Heat Pumps and Refrigeration Systems

Extending the Familiar Carnot Comparison to Reveal Improvement Opportunities When Temperatures Change



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Developed within Unified Energy B.V.

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A concise route from familiar energy systems to the proposed broader cycle-benchmark method.

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Why this programme exists

Modern life depends on combustion engines, steam engines and other heat engines that convert heat into useful power, and on heat pumps, refrigeration systems and air-conditioning systems that use power to move heat. These technologies serve different purposes, but they are governed by closely related questions about heat, work and temperature.

A heat engine receives heat at a higher temperature and converts part of it into motion or electricity. A heat pump or refrigeration system uses electricity or mechanical work to collect heat from a colder place and deliver it to a warmer one. The underlying reversed-cycle principle is the same; the useful purpose determines whether heating or cooling is emphasized.

Carnot's question

In 1824, Sadi Carnot studied steam engines and asked what limits the useful work that an ideal engine can obtain from heat.

Carnot's insight

Even an ideal heat engine is constrained by the temperatures at which it receives and releases heat.

Clausius's extension

Clausius formulated a broader reversible-cycle relation in 1854 and introduced the term entropy in 1865.

The present question

How can ideal comparisons remain fair and useful when heat is exchanged at several or changing temperatures?

Scientific progress does not always require a new physical law. Established relations can become more useful when they are organized into a clearer method. This programme examines that possibility for reversible-cycle theory: Carnot remains exact for two fixed temperatures, while the broader Clausius relation provides the scientific starting point for several or changing temperatures.

HOW THIS OVERVIEW BUILDS THE EXPLANATION

This overview starts with combustion engines, steam engines and other heat engines, followed by heat pumps, refrigeration systems and air-conditioning systems. It then introduces heat, work, cycles, fair ideal comparisons, Carnot and Clausius before presenting the proposed benchmark method. Heat exchangers appear later in relation to changing temperature paths and Thermal Matching.

Why this could matter

More relevant ideal comparisons may reveal temperature mismatches, boundary effects and design choices that simpler references hide. That can do more than rank systems: it can help quantify the performance gap, locate avoidable losses and direct attention toward promising design changes. Better comparison may therefore provide a stronger basis for engineering optimization, subject to independent review and application-specific validation.

IMPORTANT BOUNDARY

Carnot and Clausius are established nineteenth-century thermodynamics. The complete configurable method is proposed and intended for independent review. Practical designs, software and claimed energy savings require their own verification or validation.

01 | WHY THIS PROGRAMME EXISTS — CONTINUED

The whole idea, step by step

The familiar Carnot formulas remain exact for the simplest ideal case: heat enters at one fixed hot temperature and leaves at one fixed cold temperature. Many real systems exchange heat at several or continuously changing temperatures. The programme asks how established thermodynamics can be organized into an equally disciplined comparison method for those broader temperature journeys.

The familiar reference

Carnot gives exact ideal results when all heat enters at one fixed hot temperature and leaves at one fixed cold temperature.

The real-system challenge

Water, air, exhaust gas, stored heat and working fluids often warm up or cool down while heat is transferred.

The broader established rule

The Clausius reversible-cycle equality can keep each part of the heat transfer connected to its temperature.

The proposed next step

Organize these established relations into a repeatable method for constructing and checking fair ideal comparisons.

Suppose two heat-pump systems warm the same water under the same conditions. Comparing their electricity use tells us which actual system performed better in that test. It does not yet show how close either system came to the best ideal result allowed by the same temperatures, heat transfers and system boundary.

In this overview, a benchmark means that carefully defined ideal measuring stick. Reversible is the technical word used for this ideal limiting comparison. It is not a promise of a practical system design, and it is useful only when the task, boundary, known information and permitted choices are stated clearly.

THE BROADER STARTING POINT

Carnot remains exact for the familiar two-temperature case. For cycles with several or changing heat-transfer temperatures, this programme treats the broader Clausius relation as the scientific starting point for a step-by-step comparison method.

The proposed contribution is therefore not a new law of nature. It is the systematic operationalization of established thermodynamics: a repeatable route from a defined question and data to a qualified ideal result. That result can support explanation, quantification and comparison; only then can it provide a disciplined basis for investigating optimization.

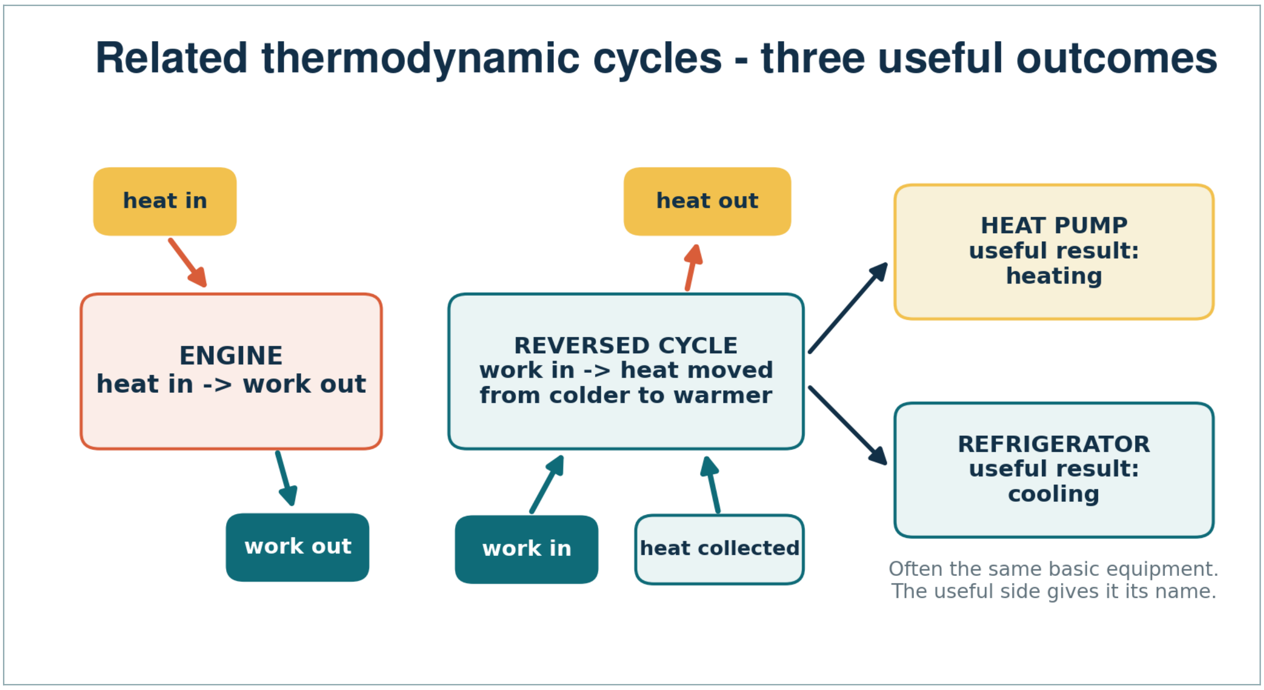
WHAT TO EXPECT

The following pages first explain the shared thermodynamic basis of combustion engines, steam engines and other heat engines, together with heat pumps, refrigeration systems and air-conditioning systems. They then introduce cycles, benchmarks, Carnot, changing temperature journeys, Clausius and the proposed method, while keeping established science separate from claims that still require review or validation.

02 | HOW THESE ENERGY SYSTEMS ARE RELATED

Heat-engine, heat-pump and refrigeration cycles are related

They do different jobs, but all move energy through a repeating process.



A heat engine takes in heat at a higher temperature. It converts part of that energy into useful work, such as turning a shaft or producing electricity. The remaining heat must go somewhere cooler.

A heat pump runs the energy process in the other direction. It uses electricity or mechanical work to collect heat from a colder place and deliver more heat to a warmer place.

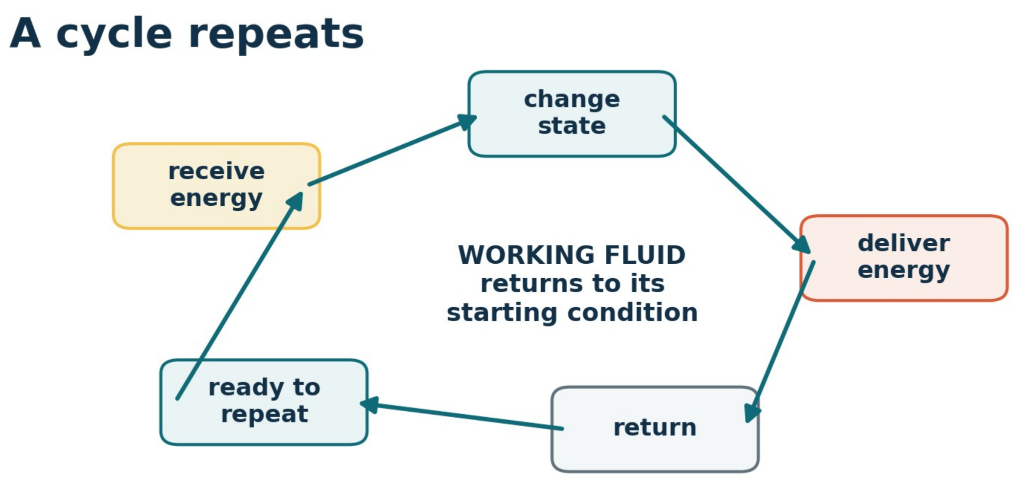
> **WHY A REFRIGERATOR IS ALSO A HEAT PUMP**
> The underlying reversed-cycle system can be essentially the same. We call it a refrigeration system when cooling the cold space is the useful result. We call it a heat pump when heating the warm space is the useful result.

Combustion-engine and steam-engine cycles produce useful work. Heat-pump, refrigeration and cycle-based air-conditioning systems use related reversed cycles to move heat. Their equipment and purposes differ, but their thermodynamic cycles can be compared through the heat and work exchanged in each repeating process.

03 | WHAT A THERMODYNAMIC CYCLE IS

What is a thermodynamic cycle?

A cycle is a repeating sequence in which a material or fluid returns to its starting condition.



The cycle repeats, but energy crosses the boundary each time.

Inside a refrigeration system, for example, a refrigerant is compressed, cooled, expanded and warmed again. It finishes the loop ready to repeat it. In a heat engine, a gas or vapour also passes through a repeating sequence that can deliver work.

The material returns to its starting condition, but the surroundings do not. Each completed cycle can move heat, produce work or require work. Thermodynamics keeps account of those energy transfers.

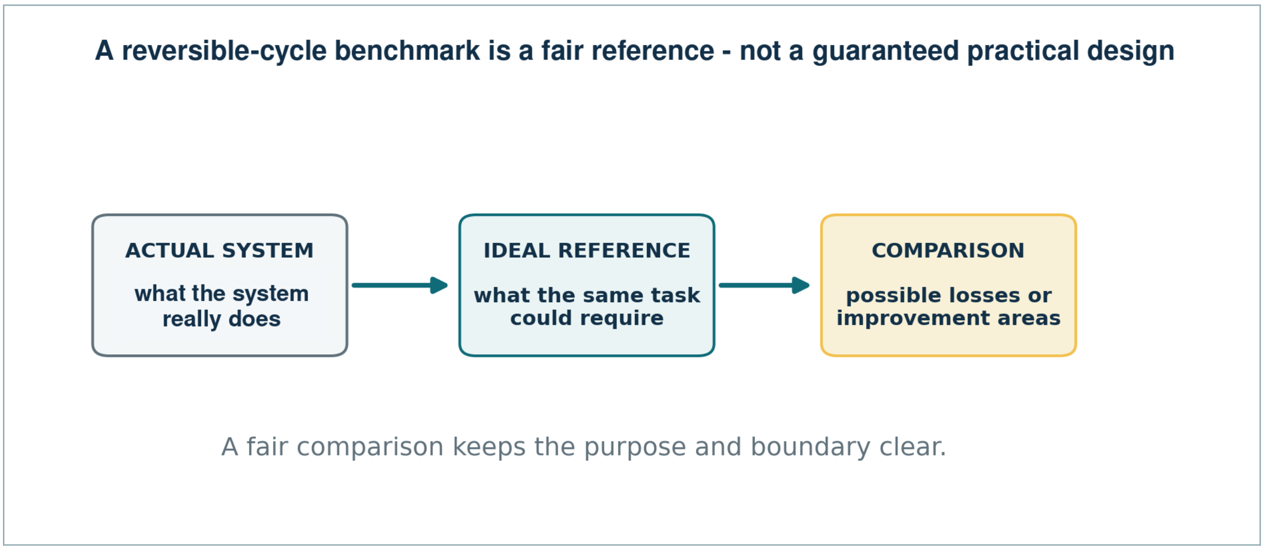
Heat	Work
Energy transferred because there is a temperature difference.	Organized energy transfer, such as a turning shaft or electrical input.

IMPORTANT. “Cycle” describes the repeating energy process. It does not mean that every heat engine, heat pump or refrigeration system has the same components or uses the same fluid.

04 | WHAT A FAIR IDEAL COMPARISON MEANS

A reversible-cycle benchmark is an ideal measuring stick

It helps separate what the task itself requires from what is lost in the real system.



Suppose two heat-pump systems warm the same water under the same conditions. One uses less electricity. That comparison is useful, but it does not yet tell us how close either system is to the best reversible reference allowed by those conditions.

A reversible benchmark imagines an ideal comparison cycle without the avoidable losses included in the benchmark definition. It is not a blueprint for a practical system. It is closer to a ruler: a reference used to measure performance.

Keep the task fixed
Heating, cooling or power output must be stated clearly.

Keep the boundary clear
We must say which heat and work transfers belong to the comparison.

State what may change
Different allowed designs can lead to different ‘best’ results.

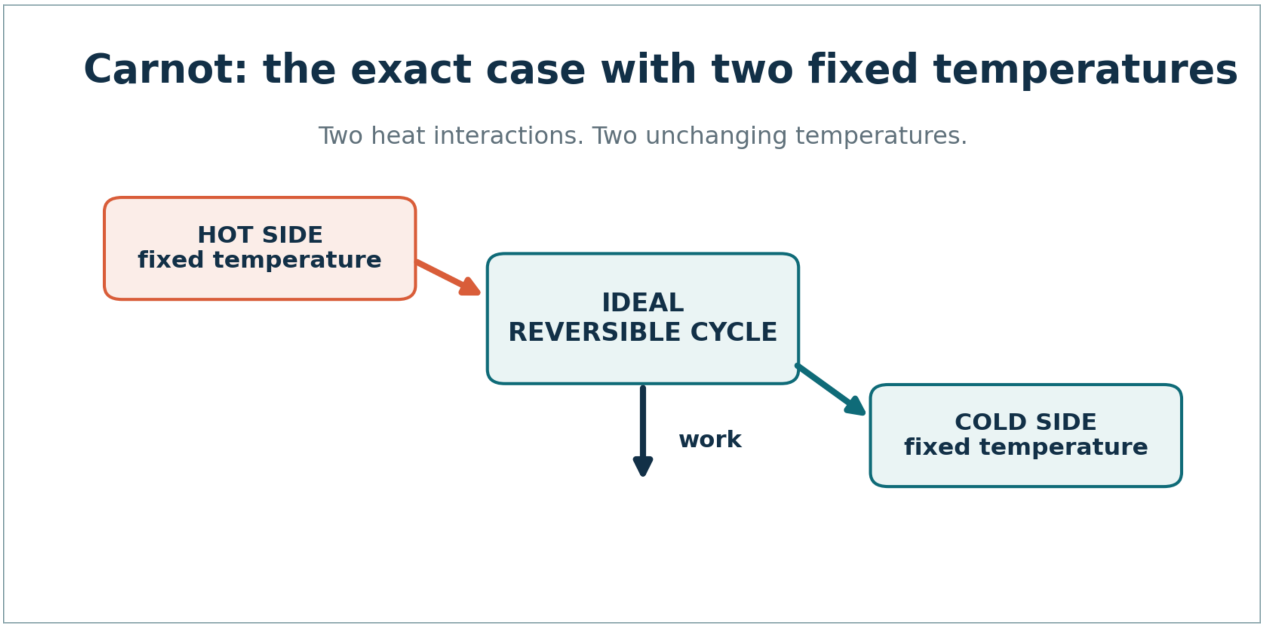
Check the result
A number is not enough; its assumptions and physical limits must also hold.

BOUNDARY
An ideal reversible benchmark is conditional on one defined task and boundary. It is not the best practical design across every fluid, component and design choice, and more than one reversible configuration may satisfy the same task.

05 | CARNOT: THE FAMILIAR SPECIAL CASE

What Carnot tells us about reversible cycles

Carnot gives the exact reversible-cycle limit when heat is exchanged at exactly two fixed temperatures.



This is one of the clearest and most important results in thermodynamics. For an ideal heat engine, the hot and cold temperatures determine the greatest possible share of incoming heat that can become work. For an ideal heat pump or refrigeration system, the same two temperatures determine the least work needed for the stated heating or cooling effect.

The familiar Carnot efficiency and heat-pump and refrigerator performance formulas are therefore not being replaced. They remain exact inside their proper two-temperature domain.

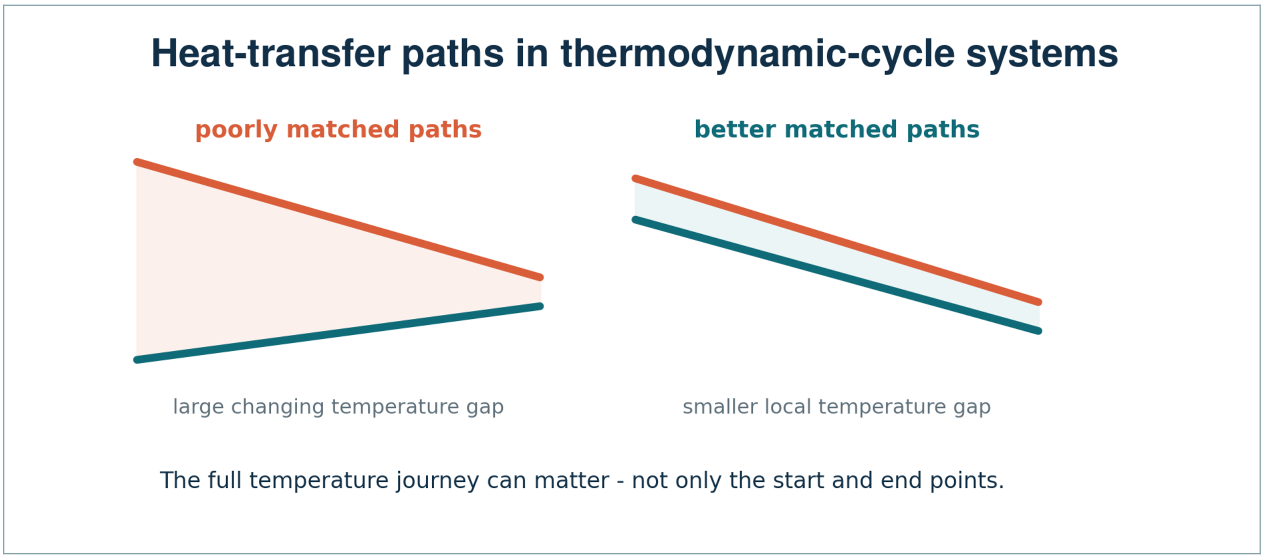
ESTABLISHED RESULT. Carnot is the exact case with one heat interaction at a fixed hot temperature and one at a fixed cold temperature. Thermodynamics calls these two isothermal interactions.

The question raised by this programme is different: how should we build an equally disciplined reversible benchmark when there are several temperatures, or when temperatures change throughout heat transfer?

06 | CLAUSIUS: THE BROADER STARTING POINT

Heat transfer in thermodynamic-cycle systems often follows a temperature journey

In heat engines, heat pumps and refrigeration systems, heat is exchanged between the thermodynamic working medium and an external thermal reservoir or flowing stream. Either side may remain at one temperature or may warm up or cool down during the transfer.



Water being heated may be the external load. Exhaust gas may be an external heat source. A refrigerant or another working fluid may circulate inside the thermodynamic cycle. Freezing, boiling, refrigerant mixtures and stored-heat materials can create still other temperature paths.

If all this behaviour is replaced by only one hot temperature and one cold temperature, useful information may disappear. The start and end temperatures alone do not always describe where heat moved or how well the two sides were matched along the way.

Several fixed steps

Heat may be exchanged at three or more separate temperature levels.

Continuous change

Temperature may rise or fall smoothly during heat transfer.

Mixed behaviour

One part may stay fixed while another part changes.

Flowing streams

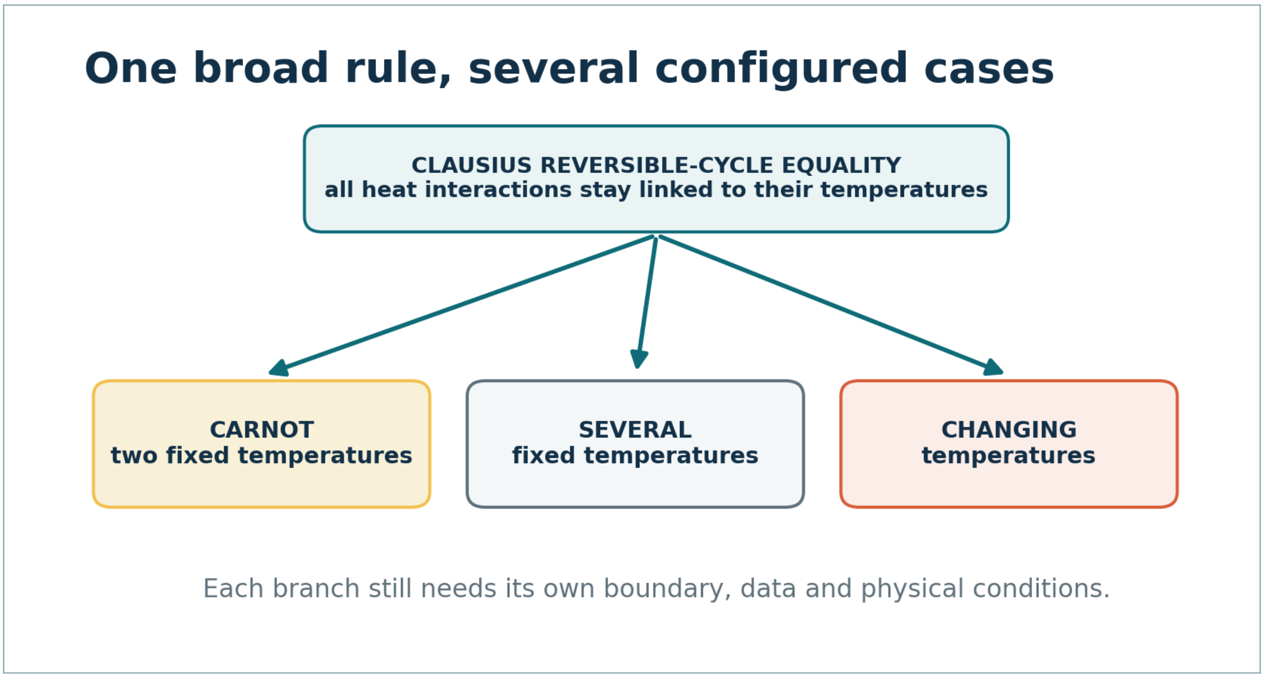
Hot and cold streams can each follow their own temperature path.

KEY IDEA. For these systems, the full heat-and-temperature path can be part of the benchmark problem.

06 | CLAUSIUS: THE BROADER STARTING POINT

Where Clausius enters reversible-cycle theory

Clausius provides an established reversible-cycle rule that can include every heat interaction and the temperature at which it occurs.



In plain language, the Clausius reversible-cycle equality keeps temperature attached to each part of the heat transfer. For a complete ideal reversible cycle, all these parts balance according to one rule.

When there is only one fixed hot temperature and one fixed cold temperature, the broad Clausius relation reduces exactly to the familiar Carnot case. When there are more heat interactions or changing temperatures, the broader form can retain that extra information.

> **NO CONFLICT BETWEEN CARNOT AND CLAUSIUS.** Carnot and Clausius are not competing theories. Carnot is recovered as the simplest exact two-temperature specialization within the broader reversible-cycle description.

The Formal Core uses a Carnot-first route because many specialists know the Carnot formulas well. A future teaching route may start with the broader Clausius relation and then show Carnot as the familiar special case. Both routes should lead to the same scientific hierarchy.

06 | CLAUSIUS: THE BROADER STARTING POINT — CONSEQUENCE

The thermodynamics is established. Its cycle-benchmark use is being extended.

The proposal does not replace Carnot or Clausius. It organizes their established relations into one configurable route for process-specific reversible benchmarks.

Classical Carnot formulas remain exact when heat is supplied and removed at two fixed temperatures. The proposed modernization addresses the wider cases in which heat is exchanged at several temperatures or along changing temperature paths.

Established foundation

The First Law and the Carnot and Clausius reversible-cycle relations are established thermodynamics.

Familiar special case

Carnot efficiency and COP formulas remain exact within their two-fixed-temperature domain.

Proposed operationalization

Data, targets, closure, admissibility and qualification are organized into a repeatable benchmark procedure.

Conditional consequence

Broader use in teaching and engineering depends on scientific review, implementation and application evidence.

A direct teaching consequence

Textbooks often present the familiar Carnot formulas as the principal reversible limits for heat engines, refrigeration systems and heat pumps. Those formulas should be identified clearly as the exact two-isothermal case, rather than as the only possible form of an ideal reversible-cycle benchmark.

The proposed teaching extension is to introduce reversible non-isothermal cycles as equally ideal when their conditions are satisfied, and to use the established Clausius equality as the broader cycle-level basis. The particular operational framework presented here remains subject to independent review.

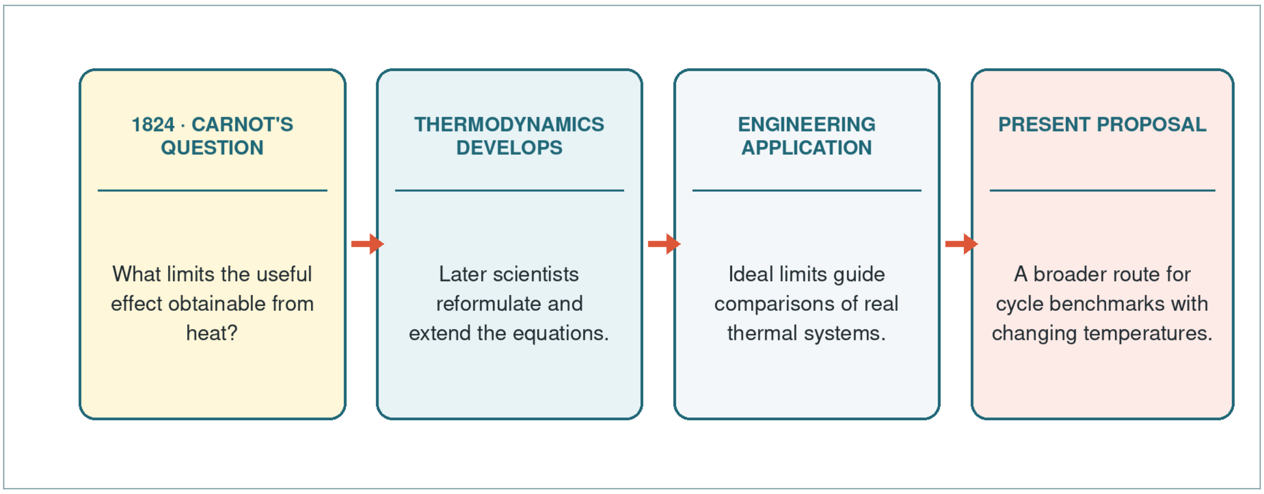
THE HIERARCHY MADE EXPLICIT

Carnot and Clausius are both established science. Carnot gives the exact ideal benchmark for one fixed hot and one fixed cold temperature. Clausius is broader: it can include every heat exchange and its temperature across a complete reversible cycle. In the proposed architecture, Clausius is therefore the parent scientific basis, while Carnot remains the exact two-temperature special case. The new contribution is the complete, configurable method built from that hierarchy—not a new law of nature.

07 | FROM SCIENTIFIC RULE TO BENCHMARK METHOD

Why a reversible-cycle benchmark can influence real technology

Carnot's historical lesson was that a general comparison can guide technology without being a specific system design.



Historical influence developed through science and engineering; the present proposal remains conditional.

Why this could matter now

Carnot did not give engineers a drawing for a better steam engine. He introduced a general way to distinguish the physical limit from the losses and restrictions of an actual steam-engine installation. Although he worked with the scientific heat theory of his time—which was later replaced—his reversible-cycle argument became part of the foundations from which classical thermodynamics developed.

The present proposal is narrower and remains subject to independent review. It asks whether the established Carnot and Clausius reversible-cycle relations can be organized more completely for systems that exchange heat at several or continuously changing temperatures. If the framework proves correct, implementable and useful, it could improve how engineers define ideal comparisons and locate avoidable losses across heat engines, power plants, heat pumps, refrigeration, industrial heat recovery and thermal storage. The actual scale of any technological, educational or energy effect remains to be demonstrated.

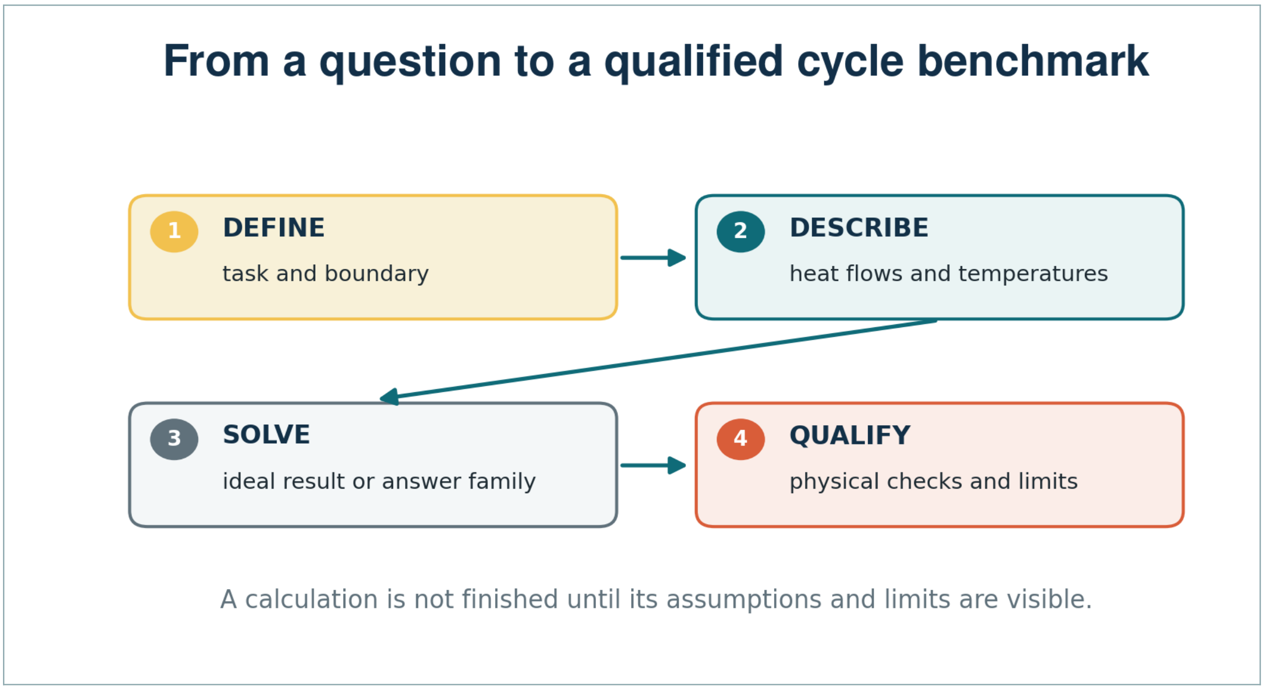
HISTORICAL ANALOGY — NOT AN EQUIVALENCE. Carnot's historical influence is established. A comparable influence of the proposed framework is not. Any future effect depends on independent review, correct implementation, validation, adoption and demonstrated application value.

07 | FROM SCIENTIFIC RULE TO BENCHMARK METHOD

From established cycle relations to a complete benchmark method

A cycle benchmark becomes usable only after the problem, data, unknowns and qualification checks are made explicit.

The Carnot and Clausius relations are established science. The proposed contribution is their complete operationalization as a configurable benchmark framework.



What is known?
Temperatures, heat duties, flow conditions and other fixed information.

What closes the problem?
Energy balance and the physical relations needed for the selected case.

What is sought?
Work, heating, cooling, an outlet temperature or another benchmark quantity.

What qualifies it?
Checks for direction, possible temperatures, cycle completion and declared limits.

CENTRAL PROPOSITION

An equality can be correct while a calculation problem is still incomplete. The proposed framework makes the missing choices and checks visible. Its ideal comparison does not need to copy the actual system's components; it must represent the same relevant task, boundary, heat transfers and temperatures. This is the role of thermodynamic process mimicking.

07 | FROM SCIENTIFIC RULE TO BENCHMARK METHOD

Four questions before trusting a cycle benchmark

A cycle-benchmark calculation is meaningful only when the comparison has been defined well enough.

1 What is the task?

Are we producing power, heating a building, cooling food, or comparing another energy service?

2 What belongs inside?

Which device, streams, heat transfers and work transfers are included in the system boundary?

3 What stays fixed?

Which temperatures, duties, flows or other conditions must be shared by the actual and ideal cases?

4 What may change?

Can the fluid, arrangement, temperatures or other design choices vary, and within what limits?

Possible outcomes

A well-defined problem may produce one benchmark value. It may also produce several allowed answers, a range, or the honest conclusion that more information is needed. The framework treats these as different valid outcomes rather than forcing a single number.

One qualified answer

Enough information and conditions select one result.

A family of answers

Several reversible configurations remain possible.

No allowed answer

The stated conditions conflict or lead outside the physical domain.

Not enough information

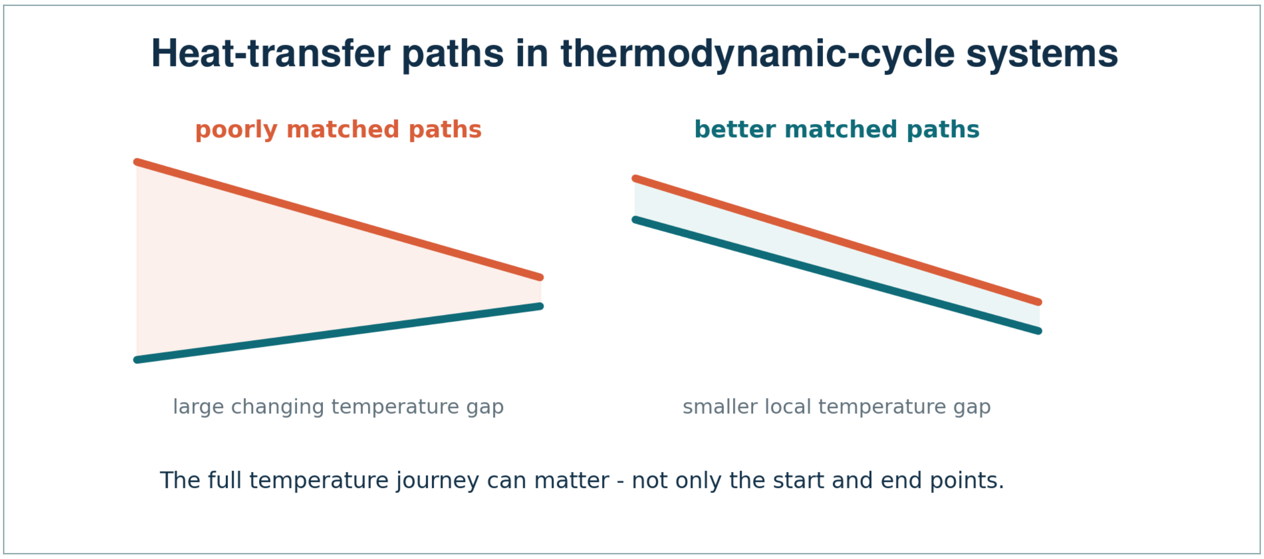
The problem is underdefined and needs more data or choices.

A SOLVER IS NOT A PROOF. Software can find a numerical answer to the equations it was given. It cannot by itself prove that the boundary, physics, comparison or claimed optimum were chosen correctly.

08 | POSSIBLE VALUE, PROGRAMME AND SCIENTIFIC STATUS

Thermal Matching: keeping temperature paths closer

Reversible heat transfer is the ideal limit in which the working medium and the external source or sink meet locally at the same temperature. In real systems, bringing those temperature paths closer can reduce avoidable loss of useful energy, but it does not by itself prove that the whole system is better.



Thermal Matching is the name used in this programme for improving how the local temperature path of the thermodynamic working medium follows the temperature path of an external thermal reservoir or flowing stream. A heat exchanger is the component or interface through which these sides interact; it is not itself a thermodynamic cycle. Confusing the two temperature paths can hide where the mismatch occurs.

The paths do not need to be horizontal or constant. Both may rise or fall. What matters is their local separation throughout the heat-transfer process.

Trajectory matching	**Conductance improvement**
Change temperature levels, flows, stages, fluid behaviour or heat distribution so the paths fit better.	Reduce resistance by changing area, materials, flow arrangement or heat-transfer coefficient.

> **DIFFERENT BUT COMPLEMENTARY.** Thermal Matching is not simply another name for making a heat exchanger larger or increasing its heat-transfer coefficient. Both approaches may be useful, but they address different limitations.

A better-looking temperature match does not automatically prove lower cost, smaller equipment or better overall performance. Those conclusions require a fair comparison and application-specific design evidence.

08 | POSSIBLE VALUE, PROGRAMME AND SCIENTIFIC STATUS

A clearer route from comparison to improvement

A process-specific reference can show why an actual cycle differs from the best reversible comparison defined for the same task.

Temperature journey Reveal where hot and cold temperature paths are poorly matched while heat is transferred.	**Boundary conditions** Show how the chosen temperatures, duties, streams and system boundary influence the comparison.
Cycle configuration Distinguish restrictions created by the selected cycle, working process or allowed design choices.	**Improvement questions** Help direct attention towards the losses, mismatches or constraints most worth investigating.

What this comparison can—and cannot—do

A more relevant benchmark can help engineers and researchers ask better questions about where conversion potential is lost and which parts of a system deserve closer study.

It does not by itself select the best system design, working fluid or investment. Lower energy use, lower cost, smaller equipment and higher reliability still require fair application-specific modelling, engineering development and validation.

CONDITIONAL VALUE. Clearer principles can support better teaching and software. Those tools can support better engineering decisions, which may reduce avoidable energy use. Each link in this chain—and the size and practical value of any improvement—must be demonstrated separately for each application.

08 | POSSIBLE VALUE, PROGRAMME AND SCIENTIFIC STATUS

From scientific specification to books, software and learning

The Formal Core, companion publications and CarnotX form connected but separately qualified layers of one programme.

CarnotX is being developed to translate selected elements of the scientific framework into methods that can be calculated, visualized, programmed, demonstrated and taught. The software does not create the scientific validity of the underlying propositions.

Reversible benchmarks

Compare an actual cycle with a physically relevant reversible reference for the same defined task.

Changing temperatures

Follow how sources, sinks and working processes warm up or cool down during heat transfer.

Thermal Matching

Explore where temperature paths align and where conversion potential may be lost.

Interactive learning

Use visual demonstrations and model examples to understand cycle behaviour and assumptions.

Current phase and programme origin

The Formal Core Specification has been completed as the governing document for focused independent academic review. The Physics & Science Book, Engineering Book and CarnotX software and demonstrations are in development. Application outcomes, software quality, educational value and energy-saving results require their own verification or validation.

The CarnotX programme was initiated and is led by Casper Helder, a mechanical engineer and developer of thermodynamic methods, software and technology. It is developed within Unified Energy B.V., which provides the scientific, engineering, software and intellectual-property foundation. CarnotX Academy is the public publication, learning and engagement layer.

Starting with tomorrow’s engineers

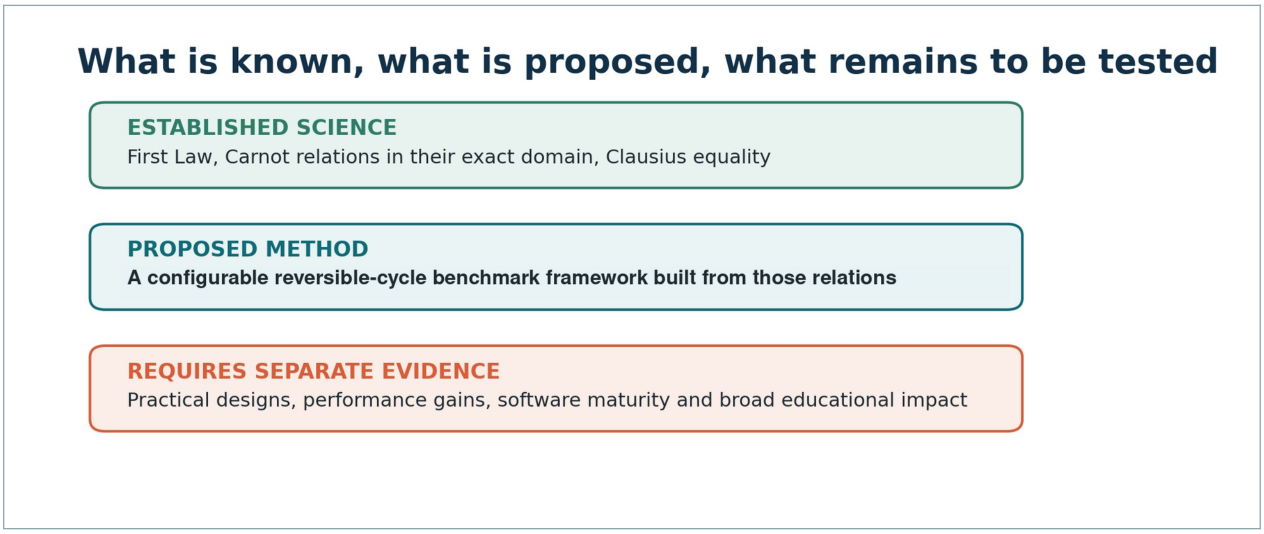
If independent review supports the proposed architecture, the programme aims to move it into education and engineering internationally, beginning with technical universities. They educate the engineers who will improve future combustion engines, power plants, heat pumps, refrigeration and air-conditioning systems. Books, visual materials and CarnotX software are intended to support learning, testing and application. Any claimed performance, cost or energy benefit must still be demonstrated separately for each application.

ROLE BOUNDARY. Dialogue, review or collaboration by professors, researchers, publishers, software contributors or industrial specialists does not by itself imply endorsement of every proposition or future application. People and organizations should be associated only with confirmed roles.

08 | POSSIBLE VALUE, PROGRAMME AND SCIENTIFIC STATUS

Clear boundaries make the cycle-benchmark proposal testable

The strength of each statement must match the evidence behind it.



Established science

The First Law of thermodynamics, the classical Carnot relations within their exact reversible two-temperature domain, and the Clausius reversible-cycle equality are established thermodynamics.

Proposed method

The proposed contribution is the systematic, complete operationalization of those relations as configurable, process-specific reversible benchmarks with explicit data, targets, closure conditions and qualification checks.

Not established by this overview

The framework alone does not prove a unique practical system design, the best working fluid, technical feasibility, equipment size, cost, reliability, a guaranteed improvement in heating, cooling or power performance, validated CarnotX functionality, universal novelty, or broad educational adoption.

REVIEW STATUS. The proposed operational architecture is intended for independent scientific review. Downstream designs, applications and performance claims require evidence appropriate to each claim.

08 | POSSIBLE VALUE, PROGRAMME AND SCIENTIFIC STATUS

Three levels of detail

Readers can stop at the level that matches their purpose.

Public Overview

This v3.2 plain-language introduction explains what the programme is about, why it may matter and what is proposed. Free direct PDF download.

Scientific Executive Summary

A bounded technical explanation for scientifically trained readers. Available as a direct PDF download.

Formal Core

The complete controlled scientific specification, equations, examples, qualification architecture and review basis. Controlled access.

Books and CarnotX

Companion books, learning materials and CarnotX software and demonstrations in development under the same scientific source and claim boundaries.

Sources and further information

Scientific source. Operationalizing the Carnot and Clausius Reversible-Cycle Equalities for Process-Specific Thermodynamic Benchmarks, Formal Core Specification, revision R167, layout edition L12, August 2026.

The scientific explanations and claim boundaries in this overview are based on the Formal Core and its cited thermodynamics literature. Selected plain-language explanations were informed by the internal draft Reader Gateways into the Framework; that draft adds no scientific evidence and does not alter the Formal Core's controlling status. Programme-status, organizational descriptions and public-access routes reflect the CarnotX Academy website as accessed on 1 September 2026.

Historical reference. Sadi Carnot, *Reflections on the Motive Power of Fire* (1824), cited for historical context only.

Website. CarnotX Academy

CONTROLLING SOURCE

If wording in this overview differs from the governing Formal Core, the Formal Core controls the scientific meaning and qualification boundary.

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