CONCEPT BRIEF · DISTRIBUTED ENERGY · CONCENTRATED SOLAR

Maintenance-Free Solar Generator

A sun-tracking mirror field and a zero-wear NASA-heritage engine, built for any high-DNI desert site

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SITE

Any high-DNI desert site (illustrated with U.S. Desert Southwest data)

PERFORMANCE REFERENCE

Matched to Sweden's record dish-Stirling system

CONTINUOUS OUTPUT

~20–26 kWe (single array)

ENGINE MAINTENANCE INTERVAL

Zero — no contacting or wearing parts

LONGEST FIELD-PROVEN RUN

14 years continuous, NASA Glenn Research Center

MIRROR MECHANISM

Solid-state MEMS, no motors or bearings

Concept and research by **Brett R. Jones** · Independent personal research · First published 18 August 2026, revised 6 September 2026

WHY THIS IS PUBLISHED OPENLY

This concept is released free for anyone to read, use, or build on. It is my hope that some person, group, or organization with the means to do so will carry it toward mass production, and that it helps in some small way to ease the world's energy needs. I am not seeking to license, sell, or commercialize it.

— Brett R. Jones

FOR RESEARCH GROUPS

The free-piston Stirling engine is independently field-proven — see Section 7. The mirror field is a harder story: **Section 6.1 identifies a real, unresolved gap** between the reliability data this brief originally borrowed (Texas Instruments' binary-switching cycle-count numbers) and the continuous, wide-angle actuation the design actually needs — serious enough that it changes the mirror field's technology-readiness assessment, not just its outdoor-qualification status. That gap, stated honestly rather than smoothed over, is the central applied-research question this brief now hands off.

1 The idea in one paragraph

A field of thumbnail-sized mirrors, each steered by a solid-state chip with no motor and no bearing, concentrates sunlight onto a single fixed point atop a ground-mounted mast. At that point sits a sealed engine with a piston that never touches anything it moves against — the same core design NASA has run continuously for fourteen years without a single maintenance visit. Matched to the same optical scale as the Swedish-engineered Ripasso Energy dish system that holds the reported world record for solar-to-electricity conversion, this combination is projected to deliver roughly **20–26 kWe of continuous, unattended power** — day after day, for decades, with no crew, no lubrication schedule, and no wear-driven failure mode in either major component. That last claim rests on an open question about the mirror field's actuation mechanism, addressed honestly rather than assumed away in Sections 2, 6, and 7.

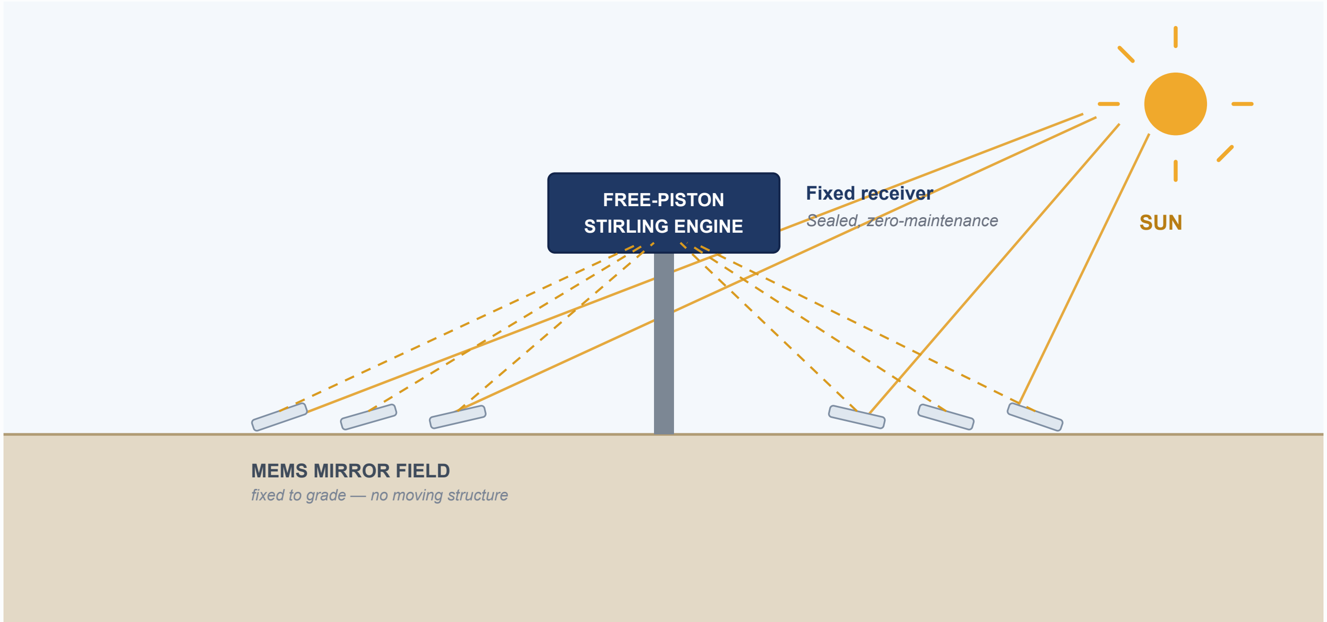

Figure 1. Cross-section, not to scale. Fixed, solid-state mirrors near grade redirect concentrated sunlight onto a single stationary receiver on a ground-mounted mast; the receiver houses the free-piston Stirling engine described in Section 3. The only motion anywhere in the system is the electrostatic tilt of each mirror element and the free-floating piston inside the sealed engine — nothing rides on a bearing, and nothing physically rotates to track the sun.

WHY THIS MATTERS

Every part of this design that could wear out has been replaced with a part that structurally cannot. That converts a normally recurring operations-and-maintenance line item into a one-time capital cost — which matters most wherever power has to run unattended and a service call is expensive or impractical: telecommunications and microwave relay sites, remote environmental and seismic monitoring stations, pipeline cathodic-protection installations, off-grid research stations, water and irrigation infrastructure, mining and industrial sites far from a road, and island or rural microgrids.

The same properties that make it attractive for hard-to-service sites — no crew, no lubrication schedule, no wear-driven failure mode — are the properties that would make continuous solar power practical to deploy and forget at scale.

2 Component one — the mirror field

Conventional concentrated-solar installations track the sun by physically rotating a large dish or panel on a motorized two-axis gimbal. That approach has a poor reputation for field reliability — figures on the order of half of all mechanical trackers drifting out of specification within five to six years circulate widely in the industry, though this brief has no primary source for that particular number and does not rest on it. What is not in dispute is the failure *mechanism*: motors, bearings, wind loading, and ground settling under a heavy moving structure are the parts that go, and they are exactly the parts one would expect to go.

This design removes the moving structure entirely. Instead of one large assembly chasing the sun, a field of small mirrors does the steering, using solid-state electrostatic actuation structurally similar to a digital projector chip (DLP/DMD) — no motor, no bearing, no rotating shaft anywhere in the mirror field.

That similarity is structural, not operational, and the difference matters. A commercial DLP/DMD chip is a **binary switch**: each mirror snaps between two fixed mechanical hard-stops roughly 20–24° apart (commonly ±10° to ±12°, up to ±17° on some chips) — it never holds an arbitrary angle in between. This design needs the opposite: **continuous, arbitrary-angle positioning** across a much wider range, to keep redirecting sunlight to a single fixed point as the sun moves across the sky and the seasons change. That distinction — and what it does to the reliability argument below — is the design's central open question, addressed directly in Section 6.1.

How hard is it actually working, in terms of cycle count?

Not very, if the only question is wear from repositioning. Tracking the sun across a 12-hour day only requires each mirror to reposition a few times a minute. Run that pace for 25 years and the cumulative actuation count lands around **100–200 million cycles**. Texas Instruments' published reliability work on DMD technology reports more than **one trillion mirror cycles** and in excess of **100,000 operating hours** demonstrated in qualification and field testing.

~100–200M	>1 trillion	~5,000×
ACTUATION CYCLES OVER 25 YEARS	MIRROR CYCLES DEMONSTRATED (TI DLP/DMD)	MARGIN BELOW THE DEMONSTRATED COUNT

That comparison is real and correctly cited, but it only answers one question: will the actuator wear out reaching that many positions. It says nothing about whether the actuator can reach the *angles* this design actually needs in the first place — TI's numbers were established on a binary device switching between two fixed hard-stops, not a continuously-variable positioner sweeping a much wider range. Cycle-count margin and angular-range capability are two separate questions, and only the first one is answered here.

Sealing is a real concern too, but a secondary one. Today's DMD chips are built for sealed indoor projectors, and moisture ingress is a known general concern for MEMS structures. Hermetic sealing against it is routine, mature practice in other outdoor MEMS applications (automotive sensors, telecom equipment) — a one-time design problem, not an ongoing maintenance burden. The larger, genuinely open question is angular range and actuation mode, covered honestly in Section 6.1 rather than assumed away here.

3 Component two — the free-piston engine

The heat concentrated by the mirror field drives a **free-piston Stirling engine** — often described as having no moving parts that touch, since its piston floats on a cushion of working gas and magnetically coupled non-contact bearings, with no crankshaft, connecting rod, or lubricated joint anywhere in the power path. It is not literally pistonless; it is a real piston with nothing left for it to wear against.

This is not an unproven concept. NASA's Glenn Research Center has operated a free-piston Stirling convertor of this type **continuously for over fourteen years with zero maintenance**, and a second unit has logged more than 110,000 cumulative operating hours — over twelve years — and remains in service. The technology has since been commercialized: Qnergy's PowerGen line, built on the same free-piston principle originally engineered for NASA, is fielded today for exactly the kind of unattended, remote, multi-year deployment this concept targets (oil and gas remote power, pipeline and cathodic-protection sites, and other installations where a service crew is expensive or impractical to send).

> **THE EFFICIENCY TRADE, STATED HONESTLY**
>
> The record-holding Swedish dish system uses a *kinematic* Stirling engine — crankshaft-linked, with real seals and wear points — to reach its reported **32%** conversion efficiency, measured on a 30 kW converter at Upington, South Africa. The free-piston alternative proposed here gives up some of that efficiency — commonly quoted in the 24–27% range, though this brief does not pin that range to a specific published measurement — in exchange for eliminating every wearing part. Given the goal is decades of unattended operation rather than peak efficiency, that is the trade this design makes.

One engine, or several?

Free-piston Stirling engines do not scale up cleanly — larger units suffer worse working-gas leakage and tighter manufacturing tolerances, a real physical limitation rather than a simple manufacturing gap. Today's commercial ceiling is Qnergy's 5.6 kW-class unit. Reaching this design's full 20–26 kWe target output means installing four to five such units side by side rather than one large engine — which the mirror field accommodates naturally, since it can already split its concentrated light across multiple independent focal points instead of feeding just one.

4 Matched against the Swedish world record

Rather than project an untested hypothetical output figure, this design's mirror field was sized to exactly match the optical aperture of the actual dish used by Ripasso Energy, a Swedish company whose system holds the reported world record for solar-to-electricity conversion efficiency, demonstrated at field scale. At that matched aperture, and using a real, measured solar resource representative of a high-quality desert siting class, the mirror field is projected to deliver essentially the same peak power the record system itself achieves — a direct validation that a field of small, solid-state mirrors can do optically what one large mechanically-tracked dish does, at the same real scale, before any claim is made about the durability upgrade in Section 3. This design is not tied to any single location; the figures below use one real, cited desert site as an illustrative example of the resource class the concept targets, not a required site. This optical-matching calculation assumes the mirror field can actually reach whatever angle is needed at any given moment — the open question in Section 6.1 is precisely whether that assumption holds.

Parameter	Value	Basis
Ripasso record efficiency (reference point)	32%	**Cited** — reported world record for a 30 kW converter at Upington, South Africa
Matched optical aperture	110.5 m²	**Geometric** — the area of an 11.86 m circular dish (πr^2), sized to the Ripasso dish diameter
Site annual solar resource (illustrative)	7.62 kWh/m²/day	**Cited** — measured direct-normal irradiance, U.S. Desert Southwest (NREL NSRDB), used as one representative example of a high-DNI desert site rather than a required location
Site peak irradiance (record condition)	960 W/m²	**Assumption** — a representative clear-sky DNI value. The Ripasso record is reported at ambient above 28 °C with no irradiance stated, so this is not a cited match to its test condition
Mirror reflectivity	92%	**Assumption** — typical of solar-grade mirrors; not a cited measurement of a specific product
Kinematic (record-matching) output	~30–33 kWe	**Derived** from the rows above — lands in the same ~30 kW class as the record unit
Free-piston (adopted, zero-maintenance) output	**~20–26 kWe**	**Derived**, using the 24–27% free-piston range discussed in Section 3

Read those labels literally. **Cited** means a source in the references supports the figure directly. **Derived** means it follows arithmetically from the rows above it. **Assumption** means it is a reasonable engineering placeholder that this brief does not have a citation for. Both assumptions sit in the optical chain, which compounds them — so the output figures are best read as an order-of-magnitude match to the record system, not a precise prediction.

5 Expected lifetimes

Component	Wear mechanism	Field-demonstrated basis	Real-world read
Mirror field (MEMS)	None — no bearings, no lubrication, solid-state actuation only	>1 trillion mirror cycles and >100,000 operating hours demonstrated (TI DLP/DMD reliability program)	Cycle-count margin only — that data is for binary switching at ~12° hard-stops, not the continuous wide-angle positioning this design needs; angular-range capability is unresolved, see Section 6.1
Engine (free-piston Stirling)	None — non-contact bearings, no crankshaft, no lubricated joint	14 years continuous, zero maintenance (NASA Glenn); a second unit past 12 years / 110,000+ hours, still running	Longest continuously-operating example currently exceeds a decade with no service event
For comparison — a conventional mechanical tracker	*Motors, bearings, gimbal wear, wind and ground-settling load*	*Widely reported to lose specification within 5–6 years, but no primary source is cited here — see the note in Section 2*	*The failure mode this design was built specifically to remove*

Put simply: the engine has both a proven mechanism and a proven reliability record. The mirror field's mechanism is proven reliable only in a mode of operation (binary switching) this design does not actually use — so unlike the engine, it is not yet fair to call the mirror field "field-proven" for this application. Section 6.1 states that directly rather than smoothing it over.

6 Open research questions

Most of the items below are bounded, checkable questions — a bench test, a chamber test, or a simulation run against tools that already exist. The first one is different: it is a genuine, unresolved feasibility question that the rest of this brief's mirror-field claims depend on, and it is placed first deliberately rather than buried.

6.1 Angular range and actuation mode of the mirror field — the central open question

Section 2's reliability argument borrows Texas Instruments' DLP/DMD cycle-count data, but that data was established on a **binary, bistable device** — each mirror snaps between two fixed mechanical hard-stops roughly 20–24° apart (commonly ±10° to ±12°, up to ±17° on some chips). This design instead needs **continuous, arbitrary-angle positioning** across a much wider range: general solar-tracking literature puts the elevation swing needed for full-day fixed-point tracking at roughly 35–40°, before accounting for the ~46° seasonal swing in solar declination over a year. The cited concentrator patent (EP2911208A1) itself specifies no maximum achievable tilt angle and provides no reliability data of its own — it demonstrates only the *control concept* (a voltage-tilt curve mapping applied voltage to mirror angle) at a single example angle of 15°, and states plainly that the mirror tilt is the *only* tracking mechanism in its design — there is no coarse mechanical stage to fall back on if the mirror's own range proves insufficient.

Continuously-variable analog MEMS mirrors do exist in the research literature — demonstrated tip/tilt ranges run up to roughly ±20–32° in the best published devices — but none of them carry TI's cycle-count reliability record, and even their best demonstrated range likely still falls short of full-year, fixed-point tracking.

Open question. Does a MEMS mirror exist, or can one be built, that combines (a) continuous rather than binary actuation, (b) angular range sufficient for full-day, full-year fixed-point tracking (very likely more than 35°, possibly needing dual-axis correction for seasonal declination), and (c) reliability anywhere approaching TI's binary-switching benchmark — or is some hybrid architecture (for example, a simple, low-part-count coarse mechanical stage handling seasonal/daily gross adjustment, with MEMS handling only fine correction) the more realistic path?

Proposed research. A literature and vendor survey of continuously-variable MEMS mirror technology (electrothermal, electrostatic comb-drive, and other actuation types) evaluated against all three requirements together, not individually — most published work optimizes for one or two of the three, not all three at once. If no existing device satisfies all three, that is itself a useful, publishable negative result, and the honest conclusion is that this design's "no moving structure" claim needs qualification pending the hybrid-architecture question above.

Two candidate paths toward closing this gap

Path A — better continuous, wide-angle MEMS actuation. The direct fix: a MEMS mirror combining continuous (not binary) positioning, angular range past 35°, and reliability approaching TI's binary-switching benchmark. This is what the open question above is asking for, and it is the more elegant fix if such a device exists or can be built.

Path B — small-range electronic mirrors relayed through fixed intermediate mirrors. Rather than asking the primary electronic mirror to reach the Stirling engine's receiver directly across the full daily-and-seasonal sun-angle range, keep it doing exactly what is already demonstrated: continuous tracking within its proven, achievable range (the same ~20–32° ceiling discussed above, or narrower). Retarget it throughout the day at whichever of several small, permanently *fixed* relay mirrors is currently reachable within that range. Each relay mirror sits at a distinct position and is angled once, at installation, to redirect whatever it receives during its assigned slice of the day onward to the one common, fixed Stirling-engine receiver. As the sun moves past what the current relay mirror can accept, the electronic mirror retargets — still within its own proven range, since the next relay mirror is positioned specifically to be reachable at that point in the day — to the next relay in the sequence, and so on through the day.

This shifts the burden of covering the full day-and-year sun-angle range onto *where the relay mirrors are positioned* rather than onto the electronic mirror's own mechanical limits — so it needs no MEMS device beyond the continuously-variable, narrow-to-moderate-range class already demonstrated in the research literature (TRL 3–4, per Section 7), not a device that also needs the unproven wide angular range. The relay mirrors themselves are entirely static — no actuation, no wear mechanism, nothing to fail; the same "cannot wear out" logic already applied to the engine. A rough sense of scale: if the electronic mirror's own continuous range is on the order of 20–40° and the total swing that needs covering is 35–90°+ across the day and year, on the order of a handful to a couple dozen relay mirrors are likely needed — far fewer than the dozens-to-hundreds a purely static field with no active retargeting would require — though the real count depends on relay geometry and needs the same SolTrace ray-tracing modeling proposed in Section 6.3 to pin down.

Two costs are worth stating honestly rather than smoothing over. First, every relay bounce adds a reflectivity loss: two reflections at the 92% assumption used in Section 4 compound to roughly 85% combined, not 92%, cutting into delivered power the same way the two flagged optical-chain assumptions already do. Second, this specific hybrid — an actively-retargeting primary combined with a set of discrete fixed relays — does not have the same direct historical precedent that the general concept of fixed secondary reflectors does. The closest real-world analogue, General Atomic's 1970s **Fixed Mirror Solar Concentrator (FMSC)**, used a continuously fixed primary paired with a small *moving receiver*, not an actively-aimed primary paired with multiple discrete fixed relays — it does support that fixed relay optics, and a **Winston compound parabolic concentrator (CPC)** secondary at the receiver to widen acceptance angle, are mature, real techniques, just not proof that this exact combination has been built before. If it holds up under modeling, this path is notable for resolving the mirror field's technology-readiness gap without requiring any MEMS hardware more advanced than what already exists in the lab today.

6.2 Outdoor hermetic sealing under concentrated flux

The Texas Instruments reliability data in Section 2 covers sealed **indoor** projector duty. It says nothing about how a DMD-class package holds up to decades of outdoor thermal cycling, humidity, and back-heating from concentrated sunlight at the receiver end of the optical chain — a materially different exposure profile.

Open question. Does a hermetically-sealed DMD-class package survive 25 years of a desert site's diurnal and seasonal thermal cycling without seal fatigue or moisture ingress?
Proposed test. Accelerated life testing in an environmental chamber, cycled to a representative desert site's measured temperature and humidity extremes, tracking seal integrity — not actuation count, which is already covered by the ~5,000× margin in Section 2 — though again, that margin concerns cycle count, not the angular-range question in 6.1.

6.3 Optical performance of a segmented mirror field vs. a single dish

Section 4's output figures assume the mirror field performs identically to the single continuous parabolic dish it is matched against by aperture area alone.

Open question. Does splitting one 110.5 m² aperture into many small, independently-steered flat elements introduce spillage or aberration losses at the fixed receiver that a continuous parabolic surface does not have?
Proposed test. Ray-tracing simulation of the proposed field geometry — NREL's own free SolTrace tool is built for exactly this — against the same irradiance and reflectivity inputs used in Section 4. This would also let a research group replace the two flagged **assumption** rows in Section 4's table with either a simulated result or a cited product spec, rather than an engineering placeholder.

6.4 Multi-engine thermal and control integration

Reaching the full 20–26 kWe target means feeding four to five independent Qnergy-class receivers from one mirror field (Section 3), not one.

Open question. What losses and control complexity does splitting concentrated flux across multiple independent focal points introduce, in real time, as the sun moves — versus the single-receiver case every cited reliability figure in this brief is actually based on?
Proposed test. Control-system simulation, or a small bench demonstration with two receivers, ahead of committing to the full four-to-five-unit array.

6.5 Closing the two flagged assumptions

The lowest-effort item on this list: the 92% mirror-reflectivity figure and the 960 W/m² peak irradiance figure in Section 4 are engineering placeholders, not citations. A group with institutional library and vendor-spec access could likely resolve both — a real product reflectivity spec, and a time/location-matched DNI figure for the actual Ripasso record conditions — well inside a week, or confirm that no better public figure exists.

7 Technology readiness

The free-piston Stirling engine is already at the top of NASA's own technology readiness scale. The mirror field is not — and the reason is not environmental adaptation, it is the actuation-mode mismatch identified in Section 6.1. The table below separates "DMD-as-actually-proven" from "what-this-design-needs" rather than treating them as one technology.

Element	TRL	Basis
Free-piston Stirling engine (as a component)	**9 — flight/field proven**	14+ years continuous NASA Glenn operation; in commercial production today (Qnergy)
Binary/bistable DMD mirror actuation (indoor duty, ~12° hard-stop switching)	**9 — flight/field proven**	>1 trillion cycles, >100,000 hours demonstrated (TI reliability program, Section 2) — but this is switching between two fixed stops, not the mode this design needs
Continuously-variable analog MEMS mirror tilt (lab-demonstrated, narrow-to-moderate range)	**3–4 — proof-of-concept to lab validation**	Up to roughly ±20–32° demonstrated in research/commercial devices; no comparable reliability data exists — see 6.1
Continuously-variable, wide-angle (35°+), outdoor-durable mirror actuation at anything near DMD-class reliability	**1–2 — basic principles observed / concept only**	No device combining all three properties has been identified; needed only if Section 6.1's Path A is the path taken — see 6.1
Fixed relay-mirror array + Winston CPC secondary (Path B's static optics)	**9 — mature, off-the-shelf**	Precision fixed mirrors and CPC secondaries are routine optical engineering; the open question is system geometry (relay count and placement), not the hardware itself — see 6.1
Full system integration (mirror field + fixed receiver + multi-engine array, coupled)	**2 — concept formulated**	No integrated demonstration yet; blocked on Section 6.1 resolving toward Path A or Path B, not just on integration effort

The gap is no longer only environment-adaptation and integration — Section 6.1 identifies a more fundamental open question about whether a mirror actuator combining continuous, wide-angle range with anything near DMD's reliability exists at all (Path A), or whether that requirement can be designed around entirely using only the mirror range already demonstrated today, relayed through fixed optics (Path B). Notably, Path B — if it survives modeling — would mean the mirror field's technology gap is closed with zero new hardware development, only system-level integration of already-mature pieces. Either way this is a bigger, more foundational research question than a bounded engineering task, and applied-research funding (NSF, DOE's Solar Energy Technologies Office, ARPA-E) is exactly the mechanism suited to answering foundational feasibility questions like this one, not only to closing narrower integration gaps.

8 Site requirements

This design is not tied to any one location. It targets the same class of site any concentrated-solar installation needs: open, low-value land with a high-quality direct-normal-irradiance (DNI) resource — desert and arid regions generally, such as the U.S. Desert Southwest, North Africa, the Middle East, the Atacama, or the

Australian Outback. Section 4 illustrates the concept using real, measured U.S. Desert Southwest data (NREL/NSRDB, cited below) because it is directly comparable to the desert site conditions the Swedish record system itself was tested under — meaning the performance match in Section 4 is not a best-case extrapolation, it is close to an apples-to-apples reproduction — not because the design requires that specific site. The mirror field and receiver both sit at grade, with no excavation and no water resource required: the free-piston Stirling engine (Section 3) uses a sealed working-gas loop with air-cooled heat rejection — the same approach Qnergy's commercial units already use in remote, waterless field deployments — so unlike an open steam cycle's water-cooled condenser, it has no need for a lake, river, or other body of water.

R References

- **NASA Glenn Research Center** — "Stirling Convertor Sets 14-Year Continuous Operation Milestone"
  Official NASA source for the 14-year continuous, maintenance-free free-piston Stirling operation record.
  https://www.nasa.gov/centers-and-facilities/glenn/stirling-convertor-sets-14-year-continuous-operation-milestone/
- **Qnergy** — PowerGen free-piston Stirling generator product documentation
  Commercial free-piston Stirling generator, 1.8–5.6 kW output range — the real basis for the multi-unit scaling figure in Section 3, and manufacturer confirmation linking the NASA-heritage design to today's commercial units.
  https://www.qnergy.com/
- **Reuters Events (CSP Today)** — "Ripasso Energy sets new solar-to-electricity world record"
  Source for the 32% figure used in Sections 3 and 4: a reported world record of 32% for a 30 kW converter at Ripasso Energy's plant in Upington, South Africa, at an ambient temperature above 28 °C.
  https://www.reutersevents.com/renewables/csp-today/technology/ripasso-energy-sets-new-solar-electricity-world-record
- **U.S. Department of Energy** — "Solar Dish Sets World-Record Efficiency"
  *A **separate** dish-Stirling efficiency record — 31.25%, achieved by Stirling Energy Systems, not by Ripasso. Included as independent corroboration that this class of machine reaches roughly 31%, and explicitly not as the source for the Ripasso figure. Some secondary coverage reports Ripasso at 34%; this brief uses the lower, better-documented 32% instead.*
  https://www.energy.gov/node/1758401
- **Douglass, Michael R.** — "DMD Reliability: A MEMS Success Story," *Proc. SPIE* 4980, Texas Instruments (2003)
  Source for the multi-billion-to-trillion-cycle and operating-hour DLP/DMD reliability data underlying the mirror-field durability figures in Sections 2 and 5.
  https://www.ti.com/pdfs/dlpdmd/153_Reliability_paper.pdf
- **Patent EP2911208A1** — "Micro-Concentrator Solar Array Using Micro-Electromechanical Systems (MEMS) Based Reflectors"
  Real, existing published patent for the MEMS solar-tracking mirror concept described in Section 2 — not a hypothetical proposal.
  https://patents.google.com/patent/EP2911208A1/en
- **National Renewable Energy Laboratory (NREL)** — National Solar Radiation Database (NSRDB)
  Source for real, measured direct-normal irradiance data for the U.S. Desert Southwest, used in Section 4 as one illustrative example of a high-DNI desert site.
  https://nsrdb.nrel.gov/

- **National Renewable Energy Laboratory (NREL)** — SolTrace: Optical modeling software for concentrating solar power systems
  Free, public ray-tracing tool proposed in Section 6.3 for validating the mirror field's optical performance and replacing the two flagged assumption figures in Section 4.
  https://www.nrel.gov/csp/soltrace.html
- **NASA** — Technology Readiness Levels
  Source for the TRL 1–9 scale used to assess each component in Section 7.
  https://www.nasa.gov/directorates/somd/space-communications-navigation-program/technology-readiness-levels/
- **Schuster, J. R., Russell, J. L. Jr., Eggers, G. H., Shelton, S. V.** — "Fixed mirror solar concentrator for power generation," General Atomic Company / Georgia Institute of Technology (1978)
  Real, deployed precedent for Path B in Section 6.1: a static primary mirror paired with a small moving receiver, including a 260 m² field built for Sandia Laboratories. Basis for citing the Fixed Mirror Solar Concentrator (FMSC) concept and its Winston CPC secondary concentrator.
  https://www.osti.gov/biblio/6808304-fixed-mirror-solar-concentrator-power-generation

§ About this publication

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Scope and status. Concept-stage engineering brief. It is not peer-reviewed, not an engineering specification, and not an offer to build, sell, or license anything. The Section 4 table labels each figure as **cited**, **derived**, or **assumption**, and the two assumptions in the optical chain are named as such rather than presented as measurements. The mechanical-tracker failure statistic in Section 2 is likewise flagged as uncited. Where a range is shown it reflects genuine uncertainty rather than false precision. The purpose here is to interest a reader in the concept — not to assert a validated result, and not to sell anything.

Sources. All material derives from publicly published sources — NASA and U.S. Department of Energy publications, a published patent, manufacturer product documentation, a peer-reviewed conference paper, and public NREL solar-resource data. Each is listed above.

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Publication record. First published 18 August 2026 at nolimitconnect.org, most recently revised 6 September 2026. Authorship and revision history are recorded in the project's public Git repository at github.com/nolimitconnect/NoLimitConnect.

How to cite.

> Jones, Brett R. *Maintenance-Free Solar Generator: A Sun-Tracking Mirror Field and a Zero-Wear NASA-Heritage Engine.* Concept brief, 18 August 2026, revised 6 September 2026.
> https://nolimitconnect.org/maintenance-free-solar-generator/

This is a concept-stage engineering brief. Figures are labeled in Section 4 as cited, derived, or assumption, and the uncited items are flagged where they appear rather than smoothed over. Where a range is shown, it reflects genuine real-world uncertainty rather than false precision.