

1GE

A Comparative Unit for Usable Work Across Energy Systems

July 2026

Abstract

Energy comparisons typically rely on raw energy density or nameplate efficiency ratings. These metrics obscure the combined performance of fuel and conversion system working together. This paper introduces 1GE (One-Gallon Equivalence), a comparative unit defined as approximately 30 MJ of usable work — derived from splitting one gallon of water into hydrogen and converting it through a realistic fuel-cell and electric drivetrain. By applying consistent efficiency assumptions across multiple fuels, 1GE reveals which energy pathways actually deliver usable work most effectively. The framework exposes significant differences between liquid transportation fuels, heating fuels, and solid/biofuels that raw energy density metrics conceal.

1. The Problem with Existing Metrics

Traditional energy comparisons rely on two primary metrics: **Energy Density** — How much chemical energy is contained per unit of fuel (MJ/kg or MJ/L). This ignores conversion efficiency entirely. **Nameplate Efficiency** — The rated efficiency of a conversion device (e.g., a fuel cell or engine) under idealized test conditions. This ignores real-world fuel characteristics and system integration losses. Neither metric answers the practical question: *How much usable work can I actually extract from a given quantity of fuel in a real system?*

2. Definition of 1GE

1GE (One-Gallon Equivalence) represents approximately 30 MJ of usable work. This baseline is derived from: - Splitting 1 gallon of water into ~0.42 kg of hydrogen (~50 MJ chemical energy) - Converting that hydrogen through a fuel cell + electric drivetrain at ~60% system efficiency The result is a standardized unit of **usable work** rather than raw energy content. This allows direct comparison across fuels with very different chemical properties and conversion pathways.

3. Master 1GE Formulas

3.1 Quantity of Fuel Required for 1GE

To deliver 1GE of usable work from a given fuel: $Q_{f_GE} = W_{GE} / (E_f \times \eta_f)$ Where: - Q_{f_GE} = quantity of fuel required to produce 1GE - W_{GE} = 30 MJ (usable work target) - E_f = chemical energy content per unit of fuel - η_f = realistic end-to-end system efficiency for that fuel pathway

3.2 1GE Index (Efficiency-Adjusted Yield)

To understand how many 1GE units a given fuel unit can produce: $I_{f_GE} = (E_f \times \eta_f) / W_{GE}$ This index reveals the effective yield of usable work per unit of fuel, accounting for both energy density and conversion efficiency. Higher values indicate more usable work per unit of fuel.

4. Cross-Fuel 1GE Analysis

Applying consistent efficiency assumptions across common fuels produces the following comparison (assuming realistic system efficiencies for each pathway):

Fuel	Quantity for 1GE	1GE Index (I_{f_GE})	Notes
Gasoline	~0.99 gal	1.01	Baseline liquid transport fuel
Diesel	~0.63 gal	1.59	Higher energy density + efficiency
Jet Fuel	~0.57 gal	1.76	High energy density, optimized systems
LPG / Propane	~0.37 gal	2.69	Very high effective yield
Natural Gas	~1.44 m ³	0.70	Lower energy density per volume
Coal	~2.9 kg	0.34	Low efficiency in small-scale use

Wood	~2.9 kg	0.35	Low energy density + conversion losses
Ethanol	~5.7 L	0.18	Low energy density, high conversion losses
Biodiesel	~2.6 L	0.38	Moderate performance
Heating Oil	~0.25 gal	4.08	Highest effective yield in class

5. Interpretation and Key Insights

The 1GE framework reveals several patterns that raw energy density metrics obscure: **Heating fuels outperform transportation fuels** when evaluated on usable work delivered per unit. Heating oil and propane show dramatically higher 1GE indices because they are typically used in high-efficiency, steady-state systems. **Liquid transportation fuels form a coherent class**. Gasoline, diesel, and jet fuel cluster in a comparable performance band when both energy density and realistic system efficiency are accounted for. **Solid fuels and biofuels underperform significantly** in small-to-medium scale applications. Low energy density combined with conversion losses makes wood, coal, ethanol, and biodiesel poor performers on a 1GE basis. **1GE measures combined fuel + machine efficiency**, not fuel alone. This exposes why some "high energy density" fuels underperform in real systems, while some lower-density fuels paired with efficient conversion pathways deliver surprising results.

6. Strategic Implications

The 1GE framework has practical implications for: **Energy transition planning** — Reveals which fuel pathways actually deliver usable work efficiently at realistic system scales, rather than relying on idealized energy density numbers. **System design decisions** — Encourages evaluation of fuel + converter as an integrated system rather than optimizing components in isolation. **Policy and investment** — Provides a clearer basis for comparing competing energy pathways when both fuel characteristics and conversion infrastructure are considered together.

7. Conclusion

1GE offers a practical, comparative unit for evaluating energy pathways based on usable work delivered rather than raw energy content or idealized efficiency ratings. By anchoring comparisons in a consistent usable-work baseline (~30 MJ), the framework exposes meaningful differences between fuels and conversion systems that conventional metrics conceal. The approach is deliberately simple and transparent. Its value lies not in precision engineering calculations, but in providing a consistent lens for comparing energy options across very different physical and chemical domains. Future refinement can add sector-specific efficiency assumptions and expand the fuel set, but the core principle remains: measure what actually gets delivered as usable work.

Signed

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July 2026