A Non-Incinerator Method for Making Storable Syngas via Induction-Heated Municipal Waste Gasification

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Sixth draft April 5, 2026 (with a lot of help from Claude and an IEEE Zoom meeting March 24 . Edited by Arel Lucas, retitled to distinguish from incineration)

Abstract

Intermittent renewable energy sources -- solar and wind -- produce power in excess of demand at increasing frequency, while also failing to meet demand at other times. Large-scale, long-duration energy storage remains a critical unsolved problem; battery technologies are insufficient at seasonal or multi-week timescales. This paper proposes an integrated solution: using excess renewable electricity as process heat for steam gasification of municipal solid waste (MSW), producing storable syngas. The key reaction -- $C + H_2O$ -> $CO + H_2$ -- requires approximately 4 MWh of heat per metric ton of carbon processed and produces approximately 12.5 MWh of chemical energy as syngas. The syngas can be stored in existing underground gas reservoirs, burned in combined-cycle turbines to recover approximately 6 MWh of electricity, or converted to methane, methanol, diesel, or sustainable aviation fuel (SAF). The critical innovation is induction heating of a molten metal pool at the base of the gasifier, which couples renewable electric power directly into the endothermic reaction without combustion. At the scale of Los Angeles County's MSW stream, the carbon content is sufficient to produce approximately twice the annual jet fuel demand of Los Angeles International Airport (LAX) at an estimated cost well under $2 per gallon, after accounting for tipping fee revenue and applicable tax credits.

1. Introduction

California and other high-renewable-penetration grids face a structurally recurring problem: midday solar generation frequently exceeds demand, resulting in curtailment or export at near-zero or negative prices, while evening demand peaks require expensive fossil-fired generation to fill the gap. This will be made worse by the installation of solar generation over the California aqueducts. Battery storage addresses some daily cycling but is economically and practically unsuitable for week-scale or seasonal storage at grid scale.

At the same time, municipalities face escalating costs and political obstacles associated with landfilling MSW. Los Angeles County generates approximately 75,000 tons of MSW per day. Approximately 40% of the mass of typical MSW is carbon, representing a substantial chemical energy store.

This paper proposes that these two problems -- excess renewable electricity and waste carbon -- can be combined into a single solution: using the electricity to drive gasification of waste carbon, storing the resulting syngas for later use as fuel or feedstock.

The underlying chemistry is not new. Steam gasification of coal and coke to produce "town gas" (a mixture of CO and H_2) was practiced industrially from the 1860s through the 1940s, when it was displaced by natural gas. What is new is the energy source for the endothermic reaction: instead of burning a substantial fraction of the feedstock to provide process heat, renewable electricity is converted to heat via induction coupling into a molten metal pool. This decouples the carbon input from the energy input, enabling a net energy gain and eliminating the carbon penalty of conventional gasification.

2. Process Chemistry and Energy Balance

2.1 The Water-Gas Reaction

The primary gasification reaction is:

$C + H_2O \rightarrow CO + H_2$ Delta H = +131 kJ/mol (endothermic)
12 18 28 2
1 1.5 2.33 .166

(A ton of carbon gives 2.5 tons of syngas, which has an energy of 6.5 MWh for CO and ~6 MWh for H_2 per ton of vaporized carbon)

Per metric ton of carbon (atomic mass 12, so approximately 83,300 mol/ton):

Heat required: approximately 3 MWh/ton carbon (reaction enthalpy)

Steam generation energy: approximately 1 MWh/ton carbon

Total electrical input: approximately 4 MWh per ton of carbon processed

The syngas produced (CO + H_2) has a combined lower heating value of approximately *12.5 MWh per ton of carbon input*, representing a thermodynamic amplification factor of approximately 3 -- a consequence of the endothermic reaction storing electrical energy as chemical bond energy.

This energy gain is not a violation of thermodynamics. The electrical energy input elevates the chemical potential of the products above the feedstock, analogous to charging a battery. The gain relative to the electrical input (12.5/4 = ~3) reflects the chemical energy already present in the carbon feedstock.

2.2 Water-Gas Shift and Product Options

The raw syngas CO and H_2 ratio of approximately 1:1 can be adjusted via the water-gas shift reaction:

$CO + H_2O \rightarrow CO_2 + H_2$

This increases hydrogen content at the expense of approximately half the carbon (which exits as CO_2 available for sequestration or further utilization). Before or after the shift reaction, the raw or hydrogen-enriched syngas can be:

Burned directly in combined-cycle gas turbines, recovering approximately 6 MWh of electricity per ton of input carbon (60% turbine efficiency on 12.5 MWh syngas)

Methanated (Sabatier reaction: $CO + 3H_2 \rightarrow CH_4 + H_2O$) to produce pipeline-compatible renewable natural gas

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Converted via Fischer-Tropsch synthesis to liquid hydrocarbons including diesel and sustainable aviation fuel (SAF)

The net electrical gain over simple combustion of MSW (typically 1.5 MWh/ton of raw waste, or approximately 4.5 MWh/ton of carbon) is modest: approximately 2 MWh/ton. However, the primary value is not marginal generation efficiency but --*dispatchable storage*--: syngas produced during periods of excess renewable generation can be stored indefinitely and converted to power or fuel on demand.

2.3 Water Balance

The gasification reaction requires approximately 1.5 tons of water per ton of carbon processed. MSW typically contains 20-30% moisture by weight, providing some but not all required water. Supplemental water can be supplied by co-processing sewage sludge, which simultaneously addresses sludge disposal costs and provides additional tipping fee revenue. Additionally, process water recovered from the gas cleanup stage can be recycled. Low net water use is desirable in dry places such as Los Angeles.

Carbon-rich supplemental feedstocks such as waste tires (high carbon, low moisture) or brush can be added to adjust the carbon-to-water ratio and supplement the MSW carbon stream.

3. The Induction-Heated Gasifier

3.1 Design Concept

The central innovation of this proposal is the use of induction heating to deliver process heat. The gasifier is a vertical, counterflow reactor with a pool of molten iron-rich metal at the base. An induction coil wound around the lower section of the reactor couples AC electrical power into the molten metal pool, which reaches approximately 1,500 °C. Incoming MSW descends through the reactor, drying and devolatilizing in the upper sections, then reacting with upward-flowing steam in the high-temperature zone near the molten pool.

Key features of this design:

No combustion. Unlike conventional gasifiers, which burn a substantial fraction of the feedstock (typically 30-40%) to supply process heat, the induction-heated design uses only electrical energy for heating. This eliminates nitrogen dilution of the syngas from air, eliminates the need for an oxygen plant, and allows the full carbon content of the feedstock to be converted to syngas.

Fast load modulation. Steam injection rate can be varied rapidly to adjust power consumption, making the gasifier a controllable electrical load suitable for absorbing curtailed renewable power. Power consumption can drop to approximately 10% of rated capacity within seconds by reducing steam injection and within milliseconds by reducing the induction heater power.

Proven component technologies. Industrial induction heating systems exist at power levels up to approximately 50 MW per unit. The gasifier chemistry is identical to town gas production practiced for over a century. The molten slag over metal pool concept is derived from long established blast furnace and induction furnace metallurgy.

Vitrified slag byproduct. Inorganic materials (glass, ceramics, ash) form a molten slag that is tapped periodically and solidifies into an inert, leachate-resistant material suitable as road base aggregate. Metals (steel, copper) are recovered from the metal pool . (Aluminum reacts with steam at this temperature contributing to hydrogen.)

3.2 Scale and Power Requirements

For a unit processing 2,500 tons per day of MSW:

Carbon fraction (40%): approximately 1,000 tons/day = 42 tons/hour

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Required electrical input: 42 tons/hour — 4 MWh/ton --approximately 160 MW continuous

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Syngas production: 10 tons/hour A— ~12.5 MWh/ton equals approximately 480 MWh/hour----chemical energy

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Recoverable electricity (combined cycle): approximately 280 MWh

A distributed group of 30-40 such units processing all of Los Angeles County's MSW stream (approximately 75,000 tons/day) would require approximately 5-6 GW of input power during operation and produce approximately 13,000 MWh/hour of syngas, storable in depleted gas reservoirs for dispatch when needed.

Three times that many units could run one third of the time (8 hours a day) at a power demand of about 20 GW.

4. Economics

4.1 Capital Cost Benchmark

The Sasol Oryx gas-to-liquids plant in Qatar (natural gas feedstock, operating since 2006) provides a useful capital cost benchmark. At approximately 34,000 barrels/day capacity, capital costs amortized over five years amount to approximately $8 per barrel of liquid fuel output. Gasifier capital costs for the proposed system are expected to be in a similar range, though direct comparison requires further engineering study.

At $8/barrel capital amortization, the capital component of production cost is approximately $0.19/gallon.

4.2 Electricity Cost

Curtailed solar power in California is increasingly available at near-zero cost to grid operators. Accounting for transmission and interconnection costs, a reasonable estimate for curtailed power is approximately $20/MWh. At 4 MWh per ton of carbon and approximately 185 gallons of liquid fuel per ton of carbon (after Fischer-Tropsch conversion with approximately 23% energy loss), the electricity cost is approximately $0.43/gallon.

4.3 Tipping Fees

Municipalities currently pay $50 to $80/ton for MSW disposal at California landfills. At 40% carbon content, this represents $125 to $200 of revenue per ton of carbon processed -- effectively a negative feedstock cost. For conservatism, tipping fee revenue is not included in the cost calculation below, though it substantially improves project economics.

4.4 IRA Sustainable Aviation Fuel Tax Credit

The Inflation Reduction Act provides a tax credit of $1.25 to $1.75 per gallon for SAF qualifying under lifecycle carbon intensity standards. Waste-derived syngas converted via Fischer-Tropsch to SAF, powered by curtailed renewable electricity, is expected to qualify for the maximum credit based on lifecycle carbon intensity because there is relatively little fossil carbon in waste. It is not clear that this subsidy will continue.

4.5 Summary Cost Estimate

Cost component	$/gallon SAF
Capital amortization (Sasol benchmark)	$0.20
Electricity at $20/MWh curtailed	$0.43
Operations and maintenance	~$0.20
Fischer-Tropsch conversion	~$0.30
Gross production cost	$1.13
Less IRA SAF tax credit	$1.25
Net production cost	negative

At $2/gallon selling price, this pathway provides a substantial margin even before accounting for tipping fee revenue, waste disposal avoided costs, or carbon credits.

4.6 Scale: The LAX Comparison

Los Angeles County generates approximately 75,000 tons/day of MSW, containing approximately 30,000 tons/day of carbon. At approximately 185 gallons of SAF per ton of carbon (after Fischer-Tropsch conversion), the theoretical maximum SAF production is approximately 5.5 million gallons per day -- approximately twice the current daily jet fuel consumption at LAX.

This comparison does not imply that all LA County waste would be converted to SAF; it illustrates the scale of the resource relative to a proximate high-value demand.

5. Validation by Prior Work

5.1 Town Gas Historical Precedent

Steam gasification of coal to produce CO/H_2 mixtures was practiced commercially at city scale from approximately 1860 through the 1940s in the United States and Europe, including Los Angeles (Fig. 1, Long Beach gas holder, 1920s). The transition to natural gas was driven by economics, not technical limitations. The chemistry is therefore fully proven at industrial scale.

5.2 Department of Defense Study

A Department of Defense study on waste-to-fuel conversion using combustion-heated gasification reported yields of approximately 8 to 10 gallons of liquid fuel per ton of raw waste. This corresponds to approximately 20 to 25 gallons per ton of carbon at 40% carbon content -- substantially less than the approximately 185 gallons/ton projected here. The difference reflects the penalty of using combustion heat (which consumes approximately 30 to 40% of the feedstock carbon) versus the induction heating approach, which adds external energy to the system. The DoD result validates the chemistry and provides a conservative floor for the energy gain from the induction approach.

5.3 Sasol Gas-to-Liquids

Sasol's commercial gas-to-liquids operations, including the Oryx plant in Qatar (2006 to present), demonstrate Fischer-Tropsch conversion of syngas to liquid fuels at scale. Capital costs, process efficiency, and operational parameters from these plants provide the basis for the cost estimates in Section 4.

6. Applications and Deployment

6.1 Grid-Scale Energy Storage

The most immediate application is grid storage. California currently curtails significant solar generation daily and uses natural gas turbines to fill evening demand. A gasifier cluster operating on curtailed daytime solar, storing syngas in depleted gas reservoirs, and dispatching combined-cycle power in the evening provides multi-day to seasonal storage with no battery degradation, no critical minerals, and no novel technology risk. If storage of CO at large scales is deemed to risky, syngas can be converted to methane at some loss of energy . The most economical compromise might be to store a few days of syngas to run turbines in the evening and convert additional production to methane for long term storage . Conversion of syngas to methane on a large scale is done in the Great Plains Synfuel Plant using a nickel catalyst.

6.2 Sustainable Aviation Fuel

Airlines face regulatory and voluntary commitments to SAF that far exceed current supply. Global SAF production in 2024 was approximately 340 million gallons -- less than one day of global aviation fuel demand. The waste-syngas pathway offers a route to large-scale SAF production from a feedstock with negative cost, located near major hub airports.

6.3 UK Application

The United Kingdom presents a particularly favorable environment for early deployment. Offshore wind is already producing power at negative prices during high-wind periods with increasing frequency. The UK has both an acute waste disposal challenge and existing expertise in underground gas storage from its historical natural gas infrastructure. The town gas chemistry was historically a British innovation. A UK pilot project would validate the technology in a regulatory environment potentially more navigable than California's.

7. Open Technical Questions

The primary technical questions requiring further engineering study are:

7,1. *Mass and water balance at scale*: detailed characterization of the content of representative MSW streams and optimization of co-feedstock blending (sludge, tires, agricultural waste) to achieve target $CO:H_2$ ratios.

7,2. *Induction heating scale-up*: industrial induction systems at 160 MW per unit represent approximately a 3x scale increase over current practice. Detailed thermal modeling of the molten pool geometry, refractory, and induction coil design is required.

7.3. Tar reforming: raw syngas from MSW gasification contains tars and other condensable organics requiring high-temperature reforming before downstream processing. The gas flow cleanup design facilitates a secondary (induction?) heated cracker downstream of the main gasifier. The gas flow cleanup design invisions a secondary (induction?) heated cracker downstream of the main gasifier . HCl, HF, and H_2S are removed by dry or wet scrubbing following tar cracking . These have to be removed to protect the turbines and the F/T catalysts.

7.4. *Pumping design for metal removal*:

periodic tapping of the molten metal pool requires engineering of systems appropriate for continuous operation. This will most likely be included in the induction heating which can lift (froth) the metal pool to a tapping outlet.

8. Concurrent Environmental Benefits

8.1. Landfills methane: Landfills emit methane, a powerful greenhouse gas . This method avoids creating methane from decomposition.

8.2 Plastices: The high temperature and gas cleanup destroys plastics of all kinds, including PVC, without releasing dioxins into the environment .

8.3. Degrading PFAS: The process also destroys “forever chemicals,” releasing the fluorine as HF. Sewage biosolids contain too much PFAS to use on crops leading to a difficult disposal problem. This could be a serious driver for acceptance since there is no known solution for disposing of “forever chemicals.”

9. Conclusion

Steam gasification of municipal waste, heated by induction-coupled renewable electricity, offers a technically conservative and economically attractive pathway for large-scale renewable energy storage. The chemistry is proven over more than a century of industrial practice. The innovation is the energy source: replacing combustion heat with induction heating fundamentally changes the energy balance, enabling net syngas production from waste carbon at a cost competitive with fossil alternatives, particularly when tipping fee revenue and renewable fuel tax credits are considered.

The convergence of three trends -- increasing renewable curtailment, escalating waste disposal costs, and urgent demand for sustainable aviation fuel makes the timing favorable for pilot-scale development. The primary barrier is not technical but institutional: identifying the engineering organization and capital source willing to take the project from concept to demonstration.

The author welcomes correspondence from engineers, utilities, waste management organizations, and airlines interested in further development.

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