Farming Liquid Air as Major Energy Commodity

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Abstract

Waste is Simply a Valuable Resource in the Wrong Place.

Burning biomass in steam engine for <10% power is just little bit better than wildfire, so here biomass = waste.

But burning biomass in my heat engine with **Liquid Air/Nitrogen**(**LA/LN)** as heat sink, its efficiency >80%, so here biomass is **precious** as gasoline, rendering 1kg biomass = 0.5kg gasoline by heat value equality, as per good biomass heat of combustion = 20MJ/kg, gasoline = 40MJ/kg.

My inventions could enable the **farmed LN** as cheap as $0.05/L by proprietary cleantech of fire-for-chill and chill-for-power.

Production line:

> grow energy grass -> burn it in my proprietary heat engine, which consumes LN as heat sink -> shaft liquefaction machine -> produce LA/LN -> feedback 70% LN production to the LN consuming heat engine for rolling-up production -> remaining LN for sale.

Burning 1kg biomass in farmland, can produce at least 2kg marketable LN after deduction of LN consumption in situ, as heat sink of heat engine, which is powering liquefaction machine.

With 80~90% veneer efficiency, future vehicle drivers need buy both fuel from gas station & LN from nearby farmers or any possible LN retailers for their fuel+LN hybrid vehicles.

Even reluctant to give up gas, its demand can be 70% off; e.g. future hybrid vehicle = 15L gas tank + 150L LN dewar, 100MPG, its range = 60L tank gas vehicle.

Omnipresent farms = dense ready LN refill & biomass reload infrastructure anywhere, include the remotest rural, better than EV in this point.

LN is also excellent energy storage with 10MJ/kg, good for Distributed Energy Resource DER.

Where there's energy, where there's vigor; after farmers joins this circular energy economy, there'll be no more hillbilly elegy.

The **epoch of Farming Liquid Air** LA = LN + Liquid Oxygen LO as major energy commodity, and the Cryogenic Heat Sink Revolution CHSR are coming! Are you ready to accept the challenge?

Contents

§1. Prelude

Now the farming season is coming in Canada, but I decide no longer farm my near 100 acres land for any crop, because fertilizer & diesel prices are upsoaring so crazy!

However I will still farm a few of acres for my own family food supply.

Since politician AOC blamed farmers' cattle/cow cause global warming by flatulence, I have emptied my livestock, though only reserve a minimal for family consumption, as we don't eat artificial meat promoted by Bill Gates.

Recently our Premier Minister Trudeau is blaming grain growers as worst emissions offenders, so I guess some farmers may fallow their farmland, and then rely on government climate-incentive benefits.

In the past years, my farming income have well supported my farmhouse-based private cleantech R&D laboratory, though farming activity did distract my effort on science and technology.

Now, without farming income support, I have to resort to external funds to continue my cleantech innovation, or may consider to port / transplant my current R&D project to a job offer with attractive compensation by a big tech or institute, even relocation is acceptable.

§2. Green energy economic cycle

With my recent great R&D progress, maybe soon I will re-farm my land for a special "energy crop" — cryogenic LA(Liquid Air) / LN(Liquid Nitrogen).

I am researching the possibility of green energy economic cycle based on LN on-farm production and hybrid power consumption.

a. The production:

Farmers use "seed" liquid nitrogen to produce more liquid nitrogen by special liquefaction machine, which is powered by burning biomass e.g. grass/straw/wood, and the "seed" liquid nitrogen is consumed as heat sink, so as to get high power efficiency from heat source of combustion.

As per Carnot's theorem, the lower the heat sink temperature, and/or the higher the heat source temperature, then the higher the heat engine efficiency.

Farmers LN production can be year-round business operation, no matter cold winter or hot summer.

In farming seasons, they will be very busy to cope with 2 tasks: growing energy grass and continuing LN production; the first task include, but not limit to: seeding, crop management, harvest, shredding, and store in barns or coverall structures.

The LN production line keeps constant rate of biomass consumption, therefore surplus biomass in summer can be consumed in winter.

b. The consumption:

* the first is in HVAC, e.g. cooler or air conditioner, as LN is extremely cold -196°C, so it's OK to simply circulate LN in evaporator, then emit itself as exhaust i.e. nitrogen gas, the major component of air.

Optionally, the Combined Cool & Power can generate by indoor air slowly heating LN, so as to provide auxiliary electricity for itself control panel & fan, even with surplus.

* the 2nd is in power generation, e.g. next generation external combustion engines, electricity generators.

These applications consume LN as heat sink, plus externally burn fuels (biomass, coal, gasoline, or heating oil) to overheat LN up to at least 300°C, then get hundreds atmosphere pressure to output torque power.

By consuming both fuel and LN, it can save tremendous fuel!

For example: a regular car fuel economy 30MPG will become **100MPG** if using gasoline + LN hybrid power.

One day in the future, most farms can produce and sell LN all over the world, then, without any fossil fuel, I can drive my biomass-LN-powered car from Canada to Mexico, just loading some initial woodchips & 100L LN tank, then intermittently buying woodchips & LN in midways from any farm alongside roads.

c. Circular economy with 2 mutual-mirrored open loops

LN consumption is an open loop with emission of exhausted nitrogen gas, e.g. if used in LN-heat-sunk heat engine, it's the thermodynamic half of a closed-loop cycle.

LN production is an open loop with re-liquefaction of nitrogen gas, just like as a mirrored one of LN consumption open loop, in the heat-pumpish dynamothermic half of a closed-loop cycle.

Only LN Farmers need assemble the two mutual-mirrored open loops in tandem, so as to indirectly convert biomass heat of combustion to cryogenic liquid air in max efficiency.

Natural macro scale atmosphere diffusion or circulation connects the two open loops together, regardless of geographic span, rendering effect of circular economy.

d. My preliminary estimation:

In a properly equipped farm with my proprietary heat engine and Linde process liquefaction machine, the LN gain is about 42%, and the equation of heat engine as input => liquefaction output:

consuming 1kg LN as "seed" + 0.2kg biomass as fuel => produce 1.42kg LN

or by other perspective:

5kg LN as "seed" + 1kg biomass as fuel => produce 7kg LN

It means: burning 1kg biomass can get 7 - 5 = 2kg net gain LN.

Or by other perspective:

depositing 1kg LN for sale after deduction of the seeding LN for sustainable production, will consume at least 1/2 = 0.5kg biomass.

Because gasoline' heat value is roughly 2 times of biomass' heat value, so by equivalence:

1kg marketable LN's heat cost = 0.5kg biomass = 0.25kg gasoline

This LN production-consumption economic cycle is **carbon neutral**, or **net-zero**, as growing biomass can absorb CO_2, though burning it emit CO_2, i.e. carbon source of the heat engine is counter-cancelled by carbon sink of energy crops on farmland with 1 year delay.

§3. It's not mandate to consume LN as seed for LN production

Almost all heat engines are using atmosphere as heat sink, e.g. a regular external combustion engine works like this: burning biomass to generate water steam→ steam propel turbine → output torque power → emit exhaust vapor to atmosphere.

In order to extract as much as possible mechanical energy from heat flow, or say for a decent efficiency, steam temperature must be very high; however, for so-so temperature in a typical Watt steam engine, efficiency is deplorably circa 10%, just a little bit better than wildfire, in sense of impact on environment; so it is never my choice.

Traditional LN industrial production only consume electric power to do liquefaction Linde process, but it's not feasible for LN farmers to consume huge electricity.

So it's only the viable choice for LN farmers to grow biomass in their own farmland, then to burn it in a properly LN-heat-sunk heat engine, for the needed power during LN production.

There is a **critical efficiency** to enable LN produced > consumed.

A commercial **threshold efficiency** for decent productivity should go beyond the critical efficiency by somewhat extent.

If the heat engine's efficiency is unluckily less than the said critical, there will be no LN net gain; else if less than the said threshold, then there is no business sense.

I will publish a separate scholar paper to present details of thermodynamic analysis, derivation, and experiment verification.

Here for convenience, just accept a practical percentage 80% as the threshold efficiency.

Although it's not difficult to reach the at-least efficiency for good net gain with my state-of-the-art heat engine shafting the prior art Linde process liquefaction machine; if using my another proprietary liquefaction machine, it can further significantly increase the efficiency.

Of course, all farmers know the gross harvest must pay back the seed, so if mandating LN as consumable seed for heat sink of heat engine, the liquefaction system has to produce more LN to pay back the seed LN.

Against the law of energy conservation? No, that's a phantom, because no matter mandate or not mandate the seeding LN, biomass is always consumed in the heat engine, just a matter of more or less biomass consumption.

In a humorous sense, farmers are used to the natural relation of seed and harvest, so even no mandate, farmers still love to choose the seed-rooted production system.

§4. Even winter cold air -30°C can still heat LN, why burn gas or biomass?

Yes, -30 Celsius degree air can spontaneously transfer heat to -196 Celsius degree LN, but burning fuel for better performance doesn't mean unnecessary waste or ridiculous farting by depanting first.

Two and one half decisive factors make me to select the non-free fuel.

a. For higher efficiency

Carnot heat engine efficiency **η** = (TH - TL)/TH, here TH = high level temperature of working medium, TL = low level temperature.

TH is decided by heat source, TL by heat sink.

So it can take both ends advantage to boost efficiency above 80% by using high grade fuel heat source for higher TH & cryogenic heat sink for lower TL, while moderate TH (**a few of hundreds Celsius degree**) makes material engineering easy.

E.g. if TH = 273 +300 = 573K, then **η** = (573 -77)/573 = 86%; else if TH = 273 +400 = 673K, then η = 89%.

In contrast, to get same η 86% with atmosphere heat sink TL= 273 +27 = 300K, the TH should be 2143K = 2143 -273 = 1870°C.

What a jump requirement in temperature, from 300°C with LN heat sink, to 1870°C with atmosphere heat sink!

That's why I emphasize on industrialization of LN heat sink production, in parallel importance with heat source production.

Unlike gasoline, biomass combustion flame is hard to reach 1000°C, but enough to heat any working medium to 300°C.

That's why farmers absolutely have the opportunity to join workforce of energy commodity producers, especially a good fit to be LN heat sink producers.

A real world heat engine is always inferior to the ideal Carnot heat engine, so it's reasonably conservative to get a discounted efficiency 80% from ideal 86% at 300°C.

Thermodynamics asserts: heat source can Never convert 100% heat energy to kinetic energy, or in other words, nothing can stop heat engine's partial heat rejection to heat sink.

Most heat engines work in a mediocre efficiency range 20% to 60%, e.g. gas car <25%, diesel car ~30%, and atmosphere is their common heat sink, which is risking of global warming with more and more engines adding to service.

Theoretically speaking, constant accumulation of global heat rejection, or say endless entropy incremental, will eventually trend to heat death of the universe.

Think to use heat pump for entropy decrement of heat sink atmosphere?

Though heat pump users feel comfy & it can save money, that's still futile in sense of entropy decrement, because work is needed to power heat pump, but generating work need more heat, and the temporarily heated medium by heat pump will eventually dissipate all acquired heat to atmosphere; then entropy incremental is furthered.

In my view, it's not the convenient **scapegoat CO2**, but the low efficiency of too many heat engines in service, which deserve to be blamed for over-rejecting heat to air heat sink.

In fact, CO2 Keeling Curve is in same tread of the everlasting increment of global heat engines quantity, so the surface effect of wrongly blaming CO2 does accidentally reflect the real culprit.

Thus even **nuclear power** may not be clean, though no CO2 emission, and judgement should be case by case: e.g. if its efficiency is above 60%, then clean; else if efficiency = 30, then not clean, as 70% energy go to heat sink atmosphere, too much!

Hence every heat engine should be responsible for less heat rejection, and work at efficiency as high as possible.

b. For heat transfer speed

LN's thermal conductivity is badly 0.13W/mK, which is < 25% of water performance, so heat transfer speed is the bottle-neck problem.

There are 3 ways to transfer heat: conduction, convection, radiation.

Here the 1st & 2nd ways are very slow, because of medium LN's bad thermal conductivity, unless pay high capital cost for jumbo heat exchangers.

Only the 3rd way can transfer heat by amazing light speed, and radiation flux is exponentially proportional to the 4th power of temperature.

Only by combustion flame, radiation heat transfer is possible.

Luckily this tech bottle-neck can be overcome by my commercial secret of optics-assisted fast heat transfer/sinking.

c. One half factor - insignifying or smoothing season influence

This factor is not too much decisive, so I assign it 0.5 factor, but still worthwhile to mention.

It's well known that a car can slightly cost user more fuel in winter, but get better fuel economy in summer.

The science behind this phenomenon:

The temperature ever-changing atmosphere is the common heat sink of all heat engines, include the internal combustion engines in vehicles, so the efficiency will be influenced by seasons.

If use atmosphere to heat LN, of course, its efficiency will be affected.

Only when neither heat source nor heat sink is atmosphere, the efficiency will keep stable.

If vehicles have my LN-heat-sunk engine, with combination of heating or cooling cab, seasonal influence still exists, however, insignificant.

Motor oil for cooling and lubrication will render more resistance in winter; and if feeding cold air, final temperature after compression will be not as hot as feeding warm hot, efficiency lowers.

My design focus on 10x more higher pressure(hydraulic grade) power, so lesser frequent cylinder motion, then lesser lubrication demand.

d. Exception:

There is one **exception** for application of the LN-CCP(**Combined Cooling & Power**), where cooling is the main purpose, but auxiliary electricity is needed for control interface, thus electricity should be generated in situ, by a compromised air-LN heat engine.

For application of the LN-CHP(**Combined Heating & Power**), as the expected space temperature is usually higher than outdoor air, and power generation is the main purpose, so high grade fuel is still required.

§5. Air liquefaction can get both LN & LO(Liquid Oxygen)

Once LN becomes a major cheap energy commodity, so will liquid oxygen get wide applications.

During air liquefaction, oxygen, boiling point -183 Celsius degree, the 21% component of air, will be firstly condensed, hence very easy to separate it from nitrogen, then gather the by-product LO, which is sometimes refereed as rocket oxidant.

LN farmers can optionally use the gathered LO to pre-cool air, or to boost combustion performance, so as to reduce or eliminate smoke or the unwanted components e.g. NO, NO2 in flue gas.

Biomass or fossil fuel + LN co-powered vehicles can also optionally equip an auxiliary LO tank, so as to improve quality of combustion & performance of heat transfer & emission, because pure oxygen combustion can render far higher flame temperature.

Both LN & LO don't need expensive high pressure heavy containers, but does need good insulation for long time storage, though evaporation minor loss is inevitable; and usually a good insulated Dewar is moderately priced.

§6. Imagine the would-be 1st generation such car

A typical configuration: 100L LN dewar, 10L LO dewar (optional), 10L gasoline tank, 200Hp optical radiation furnace external combustion engine.

Sorry, the tough biomass-as-fuel should be scheduled as 2nd generation for vehicular application, because fluid fuel can be easily controlled with ready-to-use mature technology.

The future drivers have to buy both gasoline/diesel/heating oil and LN, anyway, compared to gas-only car, they will still pay less, because they can save 70% on gas, even 50% of the saved gas cost can enough cover the LN purchase.

Of course, it seems not to save much if the calculation is based on current LN retail price, because its niche market drives it expensive, unless it's commoditizd.

Unlike a full electrified car has to rely on the resource-limited infrastructure of recharging stations, fuel+LN vehicles can quickly take refill of LN anywhere include rural farming districts, even needless of gas stations if the fuel is biomass.

Farmers can distribute their LN produce in nearby city, so no worries about supply chain for metropolitan drivers.

Given: 1kg biomass should match 5kg LN; 1kg biomass is equivalent to 0.5kg gasoline in heat value; LN density 0.8kg/L is on par with gasoline,so I set the LN tank volume capacity to be 10 times of gasoline tank.

Because production of marketable LN has consumed farmers'substantial biomass as fuel, so in a sense, LN can also be treated as a medium of **energy storage**, with thermal energy density 10MJ/kg, assuming biomass heat value 20MJ/kg.

Therefore, such kind of vehicles should be regarded as true **hybrid** type.

The efficiency will have a big leap, up to 80% by veneer efficiency, though there is no significant change in core efficiency, circa 25%.

My **veneer efficiency** concept is appraised under tentative presuming of free LN as heat sink, then only heat value of gasoline is considered.

My **core efficiency** concept, or say **overall efficiency**, is appraised under a reasonable equation of total heat value = gasoline' heat value + biomass' heat value that was spent during LN production in farmland.

As a low grade fuel, biomass price is just a fraction of high grade fuel gasoline price, though their heat values render not too big difference, so the core efficiency does not reflect market value.

In contrast, the said veneer efficiency is very close to a meaningful efficiency, and the adjective word "veneer" can be omitted.

Gedanken experiment:

It will make no sense to build an on-chassis LN liquefaction machine for coping with shortage of LN supply.

However if so, then, 25L gasoline by 3 times refilling the 10L tank, will have to be pre-consumed in parking status to make enough LN for filling the 100L LN tank, and then refill the 10L gas tank at 4th time for the final hybrid run, until all tanks are empty.

Last effect: such two procedures will get same mileage range with a gas-only car with 35L tank.

In this case, the veneer efficiency 80% no longer makes sense, but the core energy efficiency 25% is concerned, because no gasoline saved.

Assuming gasoline price = $1.5/L = $2/kg, the total 35L cost = $53 for the 2 procedures.

Given electricity consumption by industrial LN production = 1.8MJ/kg or 0.5kwh/kg, for large scale production, it seems reasonable to let LN wholesale price equal 2 times of electric energy cost:

LN price = 2 * 0.5kwh/kg * 1000kg * $0.1/kwh = $100/ton = $0.1/kg = $1.3/L

So if outsourcing industrial LN to fill the 100L tank, cost = $13, then total cost of the real hybrid drive range = 10L gas cost + 100L LN cost = $15 + $13 = $28; saved = $53 - $28 = $25, OFF rate = $25/$53 = 47%.

As to the farmed LN, no real data, but it can be roughly estimated.

The cheapest grade 3 hay forage, i.e. burnable biomass anyway, is averagely priced at $50/ton = $0.05/kg.

As burning 1kg biomass can produce 2kg LN, i.e. 1L LN need consume 0.4kg biomass, so 100L LN will consume 40kg biomass.

Once again, let me reasonably assume wholesale price of the farmed 100L LN = 2 times of burnt biomass cost = 2*40kg*$0.05/kg = $4.

Or say unit price = $4/100L = $0.04/L.

So if outsourcing LN from a farm to fill the 100L tank, then total cost of the real hybrid drive range = 10L gas cost + 100L LN cost = $15 + $4 = $19; saved = $53 - $19 = $34, OFF rate = $34/$53 = 64%.

Cost share: buy gas = $15/19 = 79%; buy farmed LN = $4/19 = 21%.

What an amazing lot of savings to be seen via computation!

But the purpose of computation is insight, Not numbers. Capisce？

§7. Imagine the first airplane powered by kerosene & LN

There are many benefits to use fuel + LN hybrid engine.

In modern jet engines, combustion temperature is very high, circa 2000°C, and such challenge does frustrate top material scientists and engineers.

The rarest metal **Rhenium** (melting point 3186°C) has to be applied in jet engine design, but its global supply is in extreme short, and its price is about 4 times of silver.

For same efficiency, a LN-heat-sunk heat engine can decrease the high temperature requirement to less than 1000°C, then material engineering will become easy, even it is possible to replace the expensive aviation kerosene by regular heating oil or the so-called Sustainable Aviation Fuel SAF.

The exhaust yet lukewarm nitrogen will usually expand **hundreds times by volume**, and this nice pure nitrogen emission around engine' fan can function as a thrust-boosting cushion to improve mach performance.

Liquid oxygen can be a good option in this application.

Not all merits, but a demerit exists: for same flight distance to empty, total volume of 2 tanks is 3 times of current single tank volume, so payload will decrease.

§8. Hesitate how to dispose mailbox spam flyers & shop packing cardboard?

Just wait for the debut of 2nd generation biomass-LN powered cars.

Then you can burn those junk fibers to power your car.

In fact, flyers paper & packing cardboard both are made of wood fibers, so it can be deemed as biomass.

Garden management, tree service, bush clearance, also generate lots of biomass residue.

Maybe the period junk accumulation can supply the same period demand on biomass fuel of your car for daily commutation/transportation.

Perhaps some future vehicle drivers will only need to buy LN, and just use any accessible daily biomass residue to heat LN on chassis.

§9. Imagine the next generation LN-cooled air conditioners & fridges

In the hot summer, the shortage of peak power electricity supply could result in non-affordable crazy hydro bill, or your household appliances fail to work, because too many air conditioners are sucking electric power from capacity-limited hydro grid.

In fact, farmer's LN is indirectly produced by solar energy, and of course, it is also the best energy storage with good energy density & containability & pumpability & portability & transportability.

When LN becomes a major cheap energy commodity, it's the time to let LN directly cool your house and food storage.

But don't pour LN indoor, because it will fatally dilute indoor oxygen concentration, so a safe such product should cool indoor air by circulating LN via heat exchange, then emitting the warmed nitrogen outdoor.

A better LN air conditioner can even generate auxiliary electricity by utilizing parasitic air-LN heat engine.

Consumers only need to periodically buy LN from omnipresent retailers, then refill LN tank for household cooling devices.

In other aspect, all climate activists blame refrigerants CFC or Freon in current cooling equipment for causing global warming, so I wish they will encourage LN replacing CFC as soon as possible.

§10. Imagine off-grid autonomy & neighborhood power supply

Farmers don't have to sell all their LN product, instead they can realize off-grid energy autonomy, even supply electricity to neighbors.

The biomass powered heat engine, which shaft is powering farmer's liquefaction machine, can also drive an electricity generator, so as to conveniently power homestead and/or transmit to nearby community.

The neighborhood power supply can be thought as micro-grid, and if the scale is further amplified, small-grid or large-grid can be shaped.

Even insulated LN pipelines are considerable infrastructure for LN-heat-sunk macro-grid aka normal grid, so as to avoid trucking job of farm by farm LN gathering.

This cleantech is specially good for islands, because almost all islands suffer from high price of electricity, e.g. Hawaii average $0.4/kwh in year 2021.

Hydro companies are reluctant to invest too much in building super long distance transmission line from city to remote rural districts, therefore, farmers will have opportunity to fill this market gap.

Such plentiful power supply will eventually usher a chain reaction to boom local economy and labor market everywhere, and there will be no more big difference between cities and farming communities

§11. Future thermal power station no longer has to sit beside big water body

Traditional thermal power stations, such as coal-fired, nature-gas-fired power plants, have to strategically sit beside big lakes or rivers or ocean, just because they all use water as working medium, & high cooling towers with hyperbola shape need massive cold water too.

Future thermal power stations should base on my cryogenic heat sink, not only for ~90% efficiency, but also for smoothing peak and valley time usage, by producing LN during valley time as a special style of energy storage.

In my inventions, nitrogen itself is just the working medium, consumably transiting from -196°C liquid state to 300°C above overheat gaseous state.

Thus **needless either big water body or skyscraper of cooling towers**.

Although power stations can produce LN during valley time, vicinal farmers still are welcome to produce LN by burning biomass, and farmed LN supply chain should be maintained stably.

Such a power station should be more flexible on heat source choice, i.e. burning coal or nature gas or LNG or biomass etc., each one or combination can be optional; and priority should be given to the non-fossil fuel -- renewable and regrowable biomass.

If a power station does not have enough own farmland, but still prefers biomass to fossil fuel for heat source, the station owner should secure biomass supply from adjacent farming community, and casually outsource LN from nearby farmers for temporary shortage of LN self production or emergencies.

As remote rural community can realize **Energy Independence** with this same cleantech by its vast farmland, therefore, too large scale thermal power station is not necessary, but should be well tailored to fit its neighboring city only.

If thermal power stations only serve cities, current generation capacity shall be downsized, and expensive long distance transmission cost shall be saved; thinking about the 40% or more delivery fee in monthly hydro bill, end users could save ~40%.

So in a sense, this is the mode of multi-partner distributed power generation, and in essence, most energy come from photosynthesis or say solar energy, even all energy if not use fossil fuel for heat source.

Farmers or hydro users can even use cheap valley electricity to produce LN if their biomass stock is in temporary short, however, later retrieving energy for power from LN, still need to burn something as heat source.

§12. Imagine the friendly help to LNG preparation

Liquid Nature Gas LNG is very important commodity of intercoastal energy trade, and exclusive liquefaction factories are built to prepare LNG before shipping.

As the boiling point of LNG is -162°C, so the more colder LN can help to liquefy nature gas, and if cheaply farmed LN is accessible anywhere in massive stock, it is possible to upscale LNG export without proportionally upscaling LNG liquefaction factories.

Building conventional LNG liquefaction factories is very expensive investment, however if taking LN advantage for precooling or directly liquefying nature gas, the re-optimized liquefaction process can simplify the technical hard core, then make new hub of LNG preparation easy buildable, as well as new hub can save major energy consumption.

By the way, as to end users of LNG, e.g. nature gas power plants, they don't have to preheat LNG into gaseous state at indoor temperature, without extract of work; because in my new invention of heat engine, LNG alone can simultaneously play three roles: cryogenic heat sink + fuel + working medium, so as to output more kinetic work.

§13. Imagine the early coming of superconductor applications

The critical temperature of synthesized material Y-Ba-Cu-O for superconductor is 92K or -181°C, which environment can be cheaply provided by liquid nitrogen.

Superconductor can be used in many fields, such as magnetic levitation, lossless electricity transmission, Magnetic Resonance Imaging (MRI) etc.

Motivated by omni-accessible dirty cheap LN, superconductor will be explored of many potential residential applications.

With up to billions dollars support all over the world, scientists are still working hard to find superconductor material that could work in normal indoor temperature.

Though an aggregate of LN itself is the best long duration energy storage in my eyes, other means are still demandable, e.g. Flywheel Energy Storage (FES) which was stymied because of significant friction loss.

Luckily enough, plentiful LN supply will reinvigorate the high energy density FES by utilizing affordable magnetic levitation for zero friction.

If LN becomes a big staple of commodity, the huge expenditure in researching new material can be saved, and researchers interest & motivation can quickly shift to then focus on superconductor applications.

§14. So it's obvious: LN shall become major energy commodity

Can so many above imaginations & scenario visualization make readers to believe that LN shall soon become major energy commodity?

I think it should do.

As per previous analysis, in a LN-heat-sunk heat engine with 80% energy efficiency, during combustion of 1kg gasoline, 10kg LN will be consumed.

Or in other words: the LN consumption is 10 times more than gasoline.

So in the future, if everywhere can see hybrid vehicles of gasoline + LN, or heating oil + LN + battery, the energy supply market will be shuffled significantly.

As efficiency is increased 3 times, so for same mileage or transportation demand of consumers, the future demand of gasoline, will shrink to 30% of current market capacity, and LN demand will be equivalent to 10/3 = 3.3 times of current gasoline market demand.

Gasoline is undoubtedly recognized as big staple commodity, so there is no reason to deny future LN, a 3.3 times more demand than nowadays gasoline, is not a major energy commodity.

Above estimation even skips the consumable LN direct cooling or refrigeration market without CFC refrigerants, which is also huge!

§15 Common sense: ash can boost biomass growth

Burning biomass for LN production, will generate lots of residue ash.

Farmers can use the by-product ash as a good fertilizer containing high concentration of potassium, so as to improve topsoil quality and farmland fertility, then they can harvest more biomass in forthcoming years.

Large scale ash return to farmland can reduce fertilizer usage, especially save major potassium fertilizer, and conserve soil moisture.

§16. Double produce: economic crops + LN

Even the prospect of farming LN is good enough, farmers don't have to self-restrict with a Hob's Choice of farming LN only, unless they are obsessed with impression of those corrupt apparatchiks, then feel no obligation to feed the swamp.

Farming LN and farming economic crops can seamlessly synergize together under well management.

Most economic crops have major biomass in stalk or straw, e.g. corn, soybeans, sorghum, wheat, rice, cotton, hemp, etc.

In comparison with inedible energy grass, farmers can have more income stream for same size farmland.

§17. Good for economy, employment, de-urbanization, social stabilization, fair resource allocation etc.

Where there are abundant energy, where there are hopes & vigor.

High density of population is not good for life quality, even bother with epidemic prevention; and some experts hint that urbanization may test positive as one of many factors for global warming.

The root energy do come from the shining Sun, and it fairly throw solar energy at peak 1000w/m^2 to everywhere, with zero discrimination on city or rural by the natural universal love.

Once this breakthrough technology get commercialized, people don't have to crowd in resource-limited cities, and there'll be no more hillbilly elegy.

To flatten the 3D density geographic curve of population distribution, government should encourage rural districts to subdivide big land into moderate size for market supply, so as to facilitate urban population shifting to rural.

Social stabilization is determined by what level of social fairness and justice, and accessible omnipresent plentiful energy can contribute positive points.

When buy a battery, buyers pay both positive and negative poles, sounds fair.

Unless swindled by pseudo-science of perpetual motion machine or magic heat engine without heat sink, no matter how high temperature, nobody believes a heat source alone generating any power, just like battery positive pole alone cannot output electricity.

So when buy then use a heat engine powered gas vehicle, I think it's unfair to only pay heat source fuel, but no pay to the common heat sink -- i.e. the atmosphere.

Now the carbon tax is enacted by government.

To my best innerstand, the carbon tax is just the payment to the common heat sink.

But carbon tax is never a smart choice, even foolish!

Why not pay farmers to produce LN as heat sink for all heat engines?

Even the carbon tax in one liter gasoline may buy 2L or more the farmed LN, which is equivalent to 0.5L gasoline in my special design of heat source - heat sink power generation.

Once biomass can be conveniently burnt as heat source in mobility application, then farmers can play two major roles: heat source producer & heat sink producer.

As a trade-off transitional best solution: let oil diggers continuously be the heat source producer, but gradually minimize its demand down to about 30% by my cleantech; let farmers be the heat sink producer.

As this disruptive technology inventor & pioneer, I feel the obligation to define a new concept for above roles play: **N**ew **W**orld **E**nergy **O**rder (**NWEO**) based on the **C**ryogenic **H**eat **S**ink **R**evolution **(CHSR)**, and will proudly usher its forthcoming.

But don't confuse it with the bad New World Order in my humble opinion, which is promoted by those deep state puppets; I prefer **Building Forward Better** through technology evolution to **Building Back Better** through political correctness.

With such unprecedented insights, my laboratory incorporation will pursue the best Environmental-Social-Governance (**ESG**) criteria.

For the common good of humankind, it's the high time to prepare the first step for the well defined **CHSR**.

And so it is!

§18. Reform agriculture tax & regulation

Farm income tax should adapt to the evolution of LN farming technology.

Once technology getting mature, farming LN farmers will call upon reforming agriculture-tax-return forms, biomass burning bylaw, and carbon tax credit.

Because LN farmers can indirectly reduce CO2 emission by tons and tons per year, so they deserve commensurable carbon tax credit.

Canada tax form T2042 - farming activity, a snapshot:

Protected B when completed

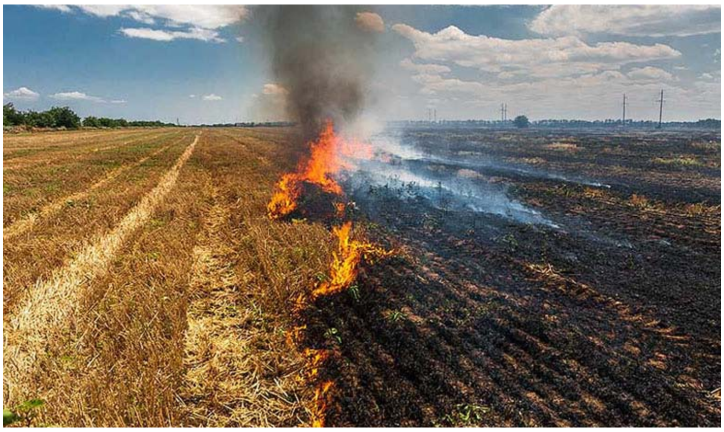
Part 3 – Income

Wheat	9371	
Oats	9372	
Barley	9373	
Mixed grains	9374	
Corn	9375	
Canola	9376	
Flaxseed	9377	
Soybeans	9378	
Other grains and oilseeds	9370	
Fruit	9421	
Potatoes	9422	
Vegetables (not including potatoes)	9423	
Tobacco	9424	
Other crops	9420	
Greenhouse and nursery products	9425	
Forage crops or seeds	9426	
Livestock sold		
Cattle	9471	
Swine	9472	
Poultry	9473	
Sheep and lambs	9474	
Other animal specialties	9470	
Milk and cream (not including dairy subsidies)	9476	
Eggs	9477	
Other commodities	9520	
Program payments		
Dairy subsidies	9541	
Crop insurance	9542	
Other payments	9540	
Rebates	9570	
Custom or contract work, and machine rentals	9601	
Insurance proceeds	9604	
Patronage dividends	9605	
Other income (specify)*	9600	0 00

Current bylaw allows farmers to conduct open-air fire by applying permission, as long as proper weather permitted & good care taken.

Future bylaw should be revised to encourage farmers feed most unwanted biomass to combustion chamber of the special heat engine that powers the air liquefaction machine for production of LN & LO.

For short stub of crops, open air burning seems not too bad, as long as main biomass is properly disposed / utilized, though without mechanic power output, whatever size open air burning, from small wild fire to large forest fire disaster, is equivalent to ruthlessly dump all heat to the vulnerable heat sink atmosphere.



But don't create a new quota system on the emerging liquid air agribusiness; Most Canadian farmers hate current quota systems.

For example, Canada government still imposes price tag $36000 per kilogram butterfat per day on dairy farmers, or roughly say, for one cow milking production capacity, farmers have to pay $36K to the oversized bureaucratic group.

A free LN market is good for healthy circular energy economy.

§19. Pre-process raw biomass by shredding or other means

Combustion chambers love small pieces formatted biomass aggregate.

Autofeeding unit usually uses auger to transfer stuffs from position A to position B, and also desire materials ready-shredded as proper size.

So pre-process must be done for big chunks of raw biomass by shredder or whatever other good methods.

Supposedly, energy consumption of pre-process is not a big deal.

This picture shows the biomass pellets in burning.

Biomass formatting is not for good looking, but for easy dispensation to combustion chamber, so no standard to mandate, the best format should be case by case, depending on system design, even a log splitter could be used to format tree trunks for a special system.

As a rule of thumb, the smaller the formatted size, the higher the cost in energy consumption, though still in auxiliary level.

§20. Impact on other biomass energy

There are many other types of biomass energy utilization, such as corn ethanol, biomass pyrolysis for biofuel, anaerobic fermentation for biogass, etc.

Of all choices, burning biomass is the simplest one, and with the creative LN-heat-sunk heat engine, half of biomass heat value can deposit in the net-gained LN product; in excellent return, off-farm LN-consuming heat engines, can convert 80% of heat value of fuels other than biomass, into mechanical energy.

That's awesome, and no other biomass energy utilization can reach such performance!

For example, extracting ethanol from corns will leave most biomass waste, though ethanol is high grade fuel, which heat value is just 2 times of regular biomass -- not too brilliant anyway; biodiesel and biogas have similar problem.

Conclusion: farming LN is the majestic energy solution of once and for all, or say Where We the farmers Go One, We the people Go All.

§21. Impact on Compressed Air Energy Storage (CAES)

In fact, LN or LA itself is a special form of energy storage - **LNES or LAES**, which is similar to the CAES, using same principle element.

Although LN can directly contact with atmosphere, however its condensation in past time did experience hundreds of atmospheric pressure, which is far higher than a practical full charged CAES; so LNES has higher density of energy: about 10MJ/kg as per prior analysis.

Unlike LNES, CAES definitely need super high grade pressure tank, and all governments enact strict bylaws for safety to regulate such class of tanks, so its cost could be prohibitively high for large scale CAES, e.g. the bankrupted Lightsail Energy, who spent $800M venture capital, used to reinforcing tanks with expensive carbon fibers.

Releasing energy from CAES usually need extra heat to go an isothermal process, some cases by waste heat, some cases by high grade heat; otherwise efficiency is unacceptably low.

It's easy to get 500 bar pressure(≈10x peak cylinder pressure of typical diesel engine), by dropping LN behind piston then overheating it up to 300°C; but CAES pressure is often capped to circa 100 bar; thus LNES can be built far more powerful, with cheaper cost per kw.

Therefore, once **LN-based Circular Energy Economy** is established, there will be no market for CAES, the old school sibling of LNES.

Even for all enumerable kinds of energy storage, it is hard to find a better one than LNES.

§22. By the way to mention non-energy applications

a. Healthcare

It is reported that many Indian patients died of shortage of LO supply during COVID pandemic.

Heartbroken for that tragedy, that won't happen if the vital liquid oxygen became cheap major staples produced by farmers.

b. Others: food industry, recreation, entertainment, education etc.

Too frivolous, out of energy theme, forgive me to skip it.

§23. Considerable strains of energy grass for LN farmers

a. Miscanthus

Photo credit to: Brittany Patterson

"I just wish we could use these lands in a little bit more productive way", West Virginia University brilliant professor Jeff Skousen said.

This energy crop don't need substantial investment on fertilizer and crop maintenance, even nothing input seems okay for a few of years, as it is like wild grass, with little touch of intrusiveness.

The max harvest can be as high as 15 tons dry matter per acre, and LN harvest after burnt all dry matter could be 30 tons LN per acre.

If LN sold at $0.05/kg, then gross income rate = $1500/acre.

In contrast, the gross income of corn crop is about $743/acre, soybean $450/acre; after deduct the heavy investment on fertilizer & cropping job, then net income is quite undesirable, even negative in a bad year, e.g. corn -$47/acre, soybean -$86/acre, as per 2019 data from reference #10.

Therefore, if technology and market permitted, farmers will have enough motivation to pursue more profitable energy crop.

b. Switch grass

Photo credit to: Leslie Boby

The biomass harvest rate is similar to the miscanthus.

c. Biden's Pelosi, sorry typo, Bidens Pilosa, invasive, may not too good

Photo credit to: Solana Thraia

This would-be energy grass may be embarrassingly a woke grass, as it's so bad grifter who monopolize massive nutrient & solar energy, and leave no chance for nearby other plants to survive.

In one word: they don't know the harmonious rule of ecology circle - live and let live!

Nowadays,this nomenclature: woke politicians, woke oligarchs, woke general, woke scientists, etc, are often appearing in news headline, so don't wonder why there is a woke grass in plant world.

I am glad to see that there are more and more people all over the world, especially pristine farmers, eventually have a rude awakening, and now they know how to identify whatever woke guys & woke stuffs.

The good aspect is: farmers don't have to sow seed every year for all invasive strains of plants, so labor & cost can be saved, then just concentrate on harvest & drying in the fall season.

d. Agricultural residues

Although most economic crops have major biomass in stalk or straw, however the ratio of residue mass to core value mass can disperse in a wide band.

To my best knowledge, cotton crop seems to render very high the-said-ratio, as its stalk is very thick, but the dried cotton is very lightweight.

Wheat and sorghum also leave heavy residues, really good choice for LN co-farming in most agriculture zones.

§24. Interface with other renewable energy

a. Photovoltaic (PV) energy

I don't support PV to be integrated with farmers' LN production line, because it's large scale installation will bock underneath plants from photosynthesis, and will deteriorate soil fertility after a few of years.

In fact, those burnt biomass in LN production line do function on par efficiency with PV, so PV no longer necessary.

As 1kg sellable LN have consumed 0.5kg biomass, which heat value = 0.5kg*20MJ/kg = 10MJ, and 1kg LN production need 0.5kwh or 1.8MJ shaft work, therefore the working core efficiency = 1.8MJ/10MJ = 18%.

In comparison, the top quality PV is 20%, but very rare yet expensive in market, and most so-so PV panels is just 13% in efficiency, with agreeable price.

That's why I feel PV no longer important after this subject cleantech successful in the future.

Even though, independent technical interface can still be done by PV-powered electric motor with speed control.

In fact, photonic energy aka light energy, is a special form of thermal energy, so from my special viewpoint, PV can be treated as a special quasi heat engine, which efficiency could be doubled or tripled by cryogenically cooling its base plate of silicon crystal.

I did not conduct the experiment yet, just a theoretical speculation, maybe pollyannaish?

At least, a peer-reviewed science paper claimed PV efficiency doubled by LN cooling, check the reference #9 in the last section.

As to solar thermal application, it can be interfaced by other way, and will discuss a similar case of geothermal interface.

b. Wind energy

The wind energy can play good with farmer's LN production line, despite it is intermittent.

An automatic transmission can be used to couple with the driving shaft of liquefaction machine, or can charge battery energy storage, then use electric power to drive it.

For the direct mechanic drive interface, my previous invention can help:

a switching-mode hydraulic power supply with adaptivity to wide range of input pressure change 100 psi ~ 5000 psi, and 3 working options of constant power, bucked or boosted constant pressure, constant flow-rate, just like a mechanical version of the modern switching-mode DC-DC power supply.

I name above gearless automatic transmission, or say smart hydraulic power supply as Wei-Trump powertrain, just in commemoration of Trump's diversity-envisioned energy policy.

c. Hydrodynamic energy

The interface is in same simplicity with wind power.

d. Geothermal energy

Temperature of power utilizable geothermal resources is about 200°C, and many nowadays heat engines for geothermal energy run in Organic Rankine Cycle (ORC), so its efficiency is as ugly as about 10% with atmosphere or separate cold well as heat sink.

Although special formulated organic working medium can have boiling point far lower than atmosphere, it still cannot be regarded as heat sink, unless consumably using great quantity of medium with hope of easy regeneration or production, however nobody is affordable for massive consumption of expensive working medium.

With my LN-heat-sunk heat engine innovation, ORC or other Sterling-type heat engine can be phased out of geothermal power, and let LN as both heat sink and working medium, heated by hot water from deep underground.

Just like using biomass as heat source to farm LN with seeding LN in rolling-up production style, geothermal resource owners can also be LN producers by using their free hot water as heat source.

For purpose of power generation or combined heat & power, geothermal resource owners can either buy cheap LN from farmers for heat sink, or independently produce LN, but not sell it, then consume it as heat sink to generate electricity in rolling-up generation mode.

§25. Side-possibility to capture carbon and more goodies

Many frenetic actions are taken to sequestrate CO_2 all over the world with bountiful funding support, such as carbon mineralization, seal in underground cavern, etc.

For on-farm LN production, it shall be a viable idea to capture CO_2 into dry ice during liquefaction process, because of higher freezing point of CO_2.

As to off-farm applications, LN-heat-sunk heat engine may have the side possibility to capture CO_2, though intentionally doing so will interfere with working efficiency more or less; so not worthy to do that.

One thing is sure and positive to efficiency: flue gas of biomass combustion can be used as prior heat source, as its heat grade is still good enough for pre-heating cryogenic working medium.

There's about 10% of gross heating value of biomass in combustion product, i.e. water vapor and CO2, the main stuff in flue gas, and almost all nowadays heat engines can not make use of the said 10%, because it's low grade heat for atmosphere-heat-sunk heat engines.

Even this extra reclaimable 10% heat value may be on par with the heat value of ethanol refined from the same biomass.

Another goody: thoroughly cleaning global air

In fact, air liquefaction-gasefaction endless cycle can thoroughly clean surface atmosphere, remove all pollutants and virus.

The global crude oil production is about 4.2 billion tons BT, and coal 7.9 BT per year.

If two third production of fossil fuel is slashed by LN commodity market share, then the height of cleaned air per year can be roughly solved from bellow equation:

4 *3.14 *6371000^2 *height *1.2kg/m^3 * 72% = 10 *(4.2 +7.9) *10^12

height = 0.27 meter = 27 cm per year, and this average height should project to all points on surface of Earth, include ocean, polar zones, or geometrically it is like as a spherical shell with 27 cm thickness.

Above equation is based on the 1:10 as the ratio of gasoline tank volume to LN dewar volume in a typical gas-LN hybrid vehicle.

§26. Forefront runners in current R&D

Picture: Manchester UK opens grid-scale LN energy storage facility.

I appreciate the UK-based company HighviewPower' great progress in this domain.

In their official website, they proudly claim: "Our CRYO platform technology is ready now".

Congratulations!

It is a centralized energy storage feasible plan, which focus on big utility clients to utilize off-peak surplus electricity for LN production as energy storage, then release the energy by LN-heat-sunk heat engine driving genset for feeding on-peak grid.

However, it does not comply with my LN-based economy cycle concept of the distributed farmland LN production for supply chain & everywhere LN consumption for HVAC and power generation.

In fact, micro-grid or Distributed Energy Resource (DER) with big storage capacity is more welcome under the current pressing call to defuse climate crisis, because of its high reliability & adaptability to many renewable energy sources.

Anyway, there is still a long way to realize my macro plan.

§27. Activate this circular energy economy by consortium

Although I can draw the blueprint for LN-based circular energy economy, even could disclose the details of my commercial secretes, e.g. the improved Internal Combustion Engine (ICE) with triple intakes: LN + LO + gasoline, however, there would be none automaker who dare to commercialize it, because there will be nowhere to economically refill LN & LO.

Also there would be none farmer who dare to massively produce liquid air with my cleantech, because just now, no large scale consumption market.

Thus this beautiful circular energy economy will be deadlocked, unless a proper activation is set up, and multiple players must involve in the pre-warming consortium to coordinate standards & progression.

I, or other more qualified expert, can be the convener of the consortium, and theme equipment makers + those big CO_2 emitters can take leading role therein, as well as agriculture ministers can represent farmers.

Governments should take the staging cost to thaw the deadlock for the common good of humankind.

If government not to pay the staging cost, then don't follow the model of circular economy in the first phase of development, but simply let farmers develop alone as electricity producer, i.e. feedback all produced LN from liquefaction machine to heat engine as consumable heat sink, only for purpose of scaling up the capacity of power generation, so as to have plentiful energy to drive commercial genset.

But government has to allow then facilitate the farmed electricity to feed in hydro grid for a decent price.

Waiting until LN-based hybrid vehicles, or cryo-air-conditioners / cryo-fridge ready to market, and encourage farmers dismount gensets then focus on LN production to meet new shaped circular energy economy.

§28. How to catch credit in this history-making cleantech evolution?

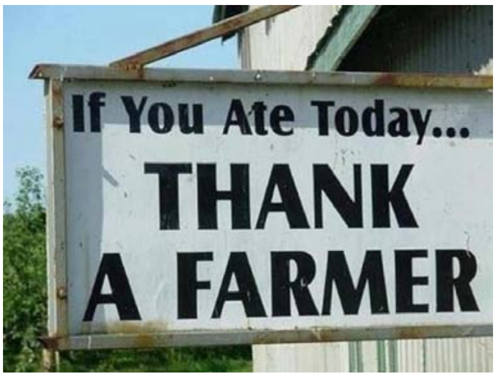
To start this newest real-net-zero economy cycle of LN production & LN consumption, smart strategic investors, and government agencies should first support me teamworking with farmers & farming communities in transition to farm LN2 by large scale as a major energy commodity.

The early bird gets the worm; so waking-up people can catch your credit in the next energy revolution.

Even a simple like emoji or share or comment on this article can be a good trace of credit; if I get inspired by your opinion, no matter appreciation or critique, you will be thanked in in my future achievement reports; or if recommendation to decision makers has sped the R&D progress, there are kudos to you; and the big financial or value-added idea contributor could become the NWEO co-definer with me.

§29. Last but not least, please ruminate on these slogans:

If you ate today, thank a farmer!



Farmers feed cities!

Some day in the future, some new slogans will appear:

If your liquid nitrogen cooling air conditioner works great, thank a farmer!

If your gas & liquid nitrogen hybrid car runs at 100 MPG, thank a farmer!

As this cleantech inventor & enabler, for the common good of humankind, I don't mind my name not mentioned in any beautiful slogan.

Reference:

1. Trudeau government targets grain growers as worst emissions offenders
2. AOC explains why ‘farting cows’ were considered in Green New Deal
3. Factsheet Biofuel Decision Support System
4. Power-plant-a-grass-might-generate-fuel-and-help-fix-damaged-mine-lands
5. Bidens pilosa — Wikipedia
6. Highview power
7. Manchester opens LAES facility
8. Switching-mode fluid power supply + Continuously Variable Transmission + regenerative brake
9. Micron-sized liquid nitrogen-cooled indium antimonide photovoltaic cell for near-field thermophotovoltaics
10. Weekly Farm Economics Release of 2020 Crop Budgets, Revised 2019 Budgets, and Up-dated Revenues and Costs
11. Planting and Managing Giant Miscanthus as a Biomass Energy Crop