

# Money From Methanol

**Fish Food to Rocket Fuel for  
Mars and Beyond**

**Kevin P. Kelly PhD, Will Patel BBA**



Welcome. I'm Kevin. I have an advanced degree in chemistry from KU and held various roles in chemical research and industry. My co-author, Will Patel, holds a business degree. We'll begin by describing chemistry that utilizes energy sources on Mars to derive useful things like fish food and power storage.

## Mars Settlement Kickstart

- Quickly develop reliable food channels and power sources
- Methanol can be synthesized from local ingredients
- Bacteria or yeast can metabolize methanol to biomass
- High-protein biomass is concentrated fish food
- Methanol also provides power storage options

Energy and water sources are vital to a Martian colony, as is food production. Methanol contributes to both. On Earth, it is being produced at a facility in Denmark that makes more than a hundred tons each day using carbon dioxide from biomass and farm waste, and hydrogen prepared from electrolysis of water using solar energy. Customers for the e-methanol include Lego Group, which needs a carbon-neutral chemical source for their plastic pieces. Carbon dioxide is the main component of Martian atmosphere, and water is abundant on the planet, so the same chemistry can operate there to produce methanol.

Deadly toxin to you or me, methanol represents a feast for fungi and bacteria that metabolize it for energy. It can be fed to organisms that are harvested to prepare food for fast-growing species such as tilapia fish. This is already being done at several locations on Earth.

Methanol also presents opportunities for power storage. In effect, it lets you shovel power from a source like a solar array into a form that can be utilized on demand in fuel cells. Methanol-burning fuel cells are already produced on this planet, as remote unattended power sources, for example.

## Hydrogenation of CO<sub>2</sub>

### Local stuff, useful things

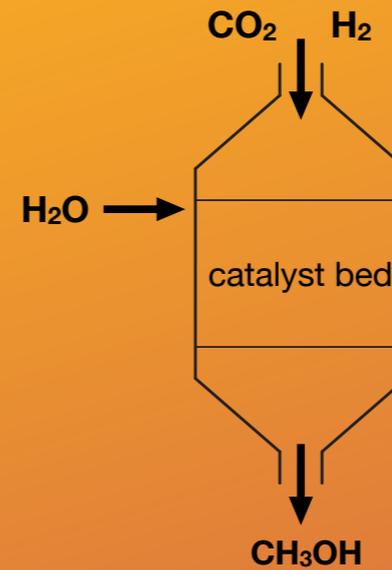
- Methanol from carbon dioxide is exothermic ( $\Delta G_0$  ca. -50 kJ/mol)
- Typical catalyst:
  - Cu particles on alumina or zirconia + Zn-oxide or other enhancers
  - Shaped into pellets to make catalyst bed
- Typical Earth conditions: 200-270 °C, 10-50 bars each of CO<sub>2</sub>, H<sub>2</sub>
- Very selective for methanol, up to 90+%
- Single pass conversion 30-40% - helped by recycle loops

Hydrogenation of carbon dioxide to methanol occurs readily over copper-based catalysts at elevated temperature, liberating energy as heat, nature's way of saying it wants something to happen. That heat has to go somewhere. Losing it is akin to buying food, then letting it spoil instead of eating it. On Mars, precious solar energy is needed to split water, and to compress and preheat reaction ingredients. Solar power there is a daily allotment based on the size of your array. If you don't use it, you lose it.

You can utilize reaction energy to preheat reaction ingredients or even transform it into electricity, but that can be an arduous task for a startup colony. Advanced catalytic systems allow the reaction to proceed at lower temperatures, minimizing the heat capture problem, a good idea for a Mars operation.

## Methanol Reactor

- Pressure regulated - reactants as makeup gas
- Spray in water
- Hot methanol-enriched water forced out
- Gas recycle loop (not shown) increases yield
- Recaptured energy preheats ingredients



Humans on Mars require oxygen, typically taken from water. Robert Zubrin estimates this requires electrolysis of 1 kilogram of water per day for each inhabitant. The byproduct is hydrogen gas. The Martian atmosphere, 95% carbon dioxide, can be pressurized, causing CO<sub>2</sub> to liquefy at ambient temperatures. Carbon dioxide and hydrogen are heated and compressed, then introduced to the catalyst. Added water absorbs heat liberated by the reaction and carries away methanol as it is produced. A hot, aqueous solution expresses from the bottom. Congratulations! You are now a Mars methanol mogul, and you just made something that can be burned in fuel cells or fed to organisms that are eaten by fish.

## Methanol as Energy Currency

$\text{CH}_3\text{OH}$  = liquid sunshine (your energy piggybank)

- Methanol / water + oxygen + fuel cell = electricity
- Portable electric energy for:
  - Batteries
  - Space Heaters
  - Pumps
  - Transport?



Electrolysis of water to make oxygen and hydrogen consumes energy. But the methanol produced by hydrogenation of carbon dioxide represents an energy store. It can be combined with oxygen in a fuel cell—a way of banking and utilizing energy used to split water. Since that energy came from solar panels, a fixed energy input controlled by the solar flux and the size of the array, oxidation of methanol in fuel cells provides a mechanism for coping with fluctuating Martian power demand, and also a backup power source, at night or during dust storms, for example.

## Expansion Opportunities

### Business “down the road”

- Chemical feedstocks for many uses  
(e.g. ethylene, formaldehyde, acetic acid, methyl tertiary-butyl ether (MTBE), dimethyl ether (DME), etc.)
- **Liquid propellant for plasma rockets**

Methanol is a starting point for many useful chemicals. If the methanol reactor is built with modularity, it can be reconfigured to perform other chemical reactions. Alternately, it might be supplemented with additional reactors configured to produce downstream chemicals from methanol. This ensures expansion opportunities for “Mars methanol moguls” once basic needs are satisfied and population increases. A novel, albeit more speculative use for methanol solutions is as propellant for plasma rockets. We’ll return to that, but now let me introduce my coauthor, Will Patel, who will cover the economics of a methanol operation. Will received a business degree from UT Austin, with emphasis on entrepreneurial factors. Please welcome my co-author, Will Patel.

## Imagine This

- **Modular reactor kit** → plugs into **water + CO<sub>2</sub> + sunlight**
- Outputs **staples**: food/feed (bio), electricity (fuel cells), heat (reuse)
- **Add-on when ready**: propellant precursor skid
- Operated **locally** via **franchise / lease-to-own**
- **Additive** to any colony; no redesign of local systems



Imagine a group of colonists who travel to Mars to operate an industrial chemical business to supply other colonists. Think business-in-a-box: a self-contained kit, shipped to Mars in cargo holds, that turns local inputs into survival staples on day one.

Colonists operate it. The wrapper is a franchise or lease-to-own, so value accrues on Mars. The optional propulsion module comes later; we don't overreach early—staples first, then rocket propellant. The key idea is that business is additive. The reactor plugs into your settlement without forcing you to rebuild your infrastructure, and begins providing staples quickly.

## Owning Your Martian Micro-Refinery

- **Earth provides:** capital, training, spares, software updates



- **Mars provides:** operators, siting, real demand & field data

- **Flexible lanes:** PPP, corporate franchise, co-op lease-to-own
- **Standards + shared telemetry** → reliability, safety, faster upgrades

- Clear **path to local ownership** (or stay in-network for scale benefits)



Earth's role is to enable, not to own—Earth fronts the ramp: financing, training, spares, software. Mars brings the operators and the reality checks. Field data loops back for analysis to improve the fleet.

Financing fits the polity: public-private, corporate franchise, or co-op for settlers.

A commitment to standards and telemetry ensures that reliability scales. Operators can buy out or remain in-network.

## Scaling Production

- **Path is incremental:** Outposts → Towns → Regions
- **Today:** pilot a **few units**, publish results, agree on **standards**
- Standards let future deployments **click together**
- With many units, a **mesh** of supply nodes emerges
- Colonies **trade staples & capacity, share spares**, cover each other in storms
- **Data Telemetry** → **learning system:** fixes in one place uplift everyone



It's important to start small: first outposts, then towns, then regions. The initial move is modest—pilot a handful of units, publish the data, and codify standards. Standards make subsequent deployments plug-and-play across different colonies and polities.

As units accumulate, they act like a mesh: settlements trade staples, pool together spares, and offer mutual aid during downtime or dust storms. Because every unit shares telemetry, the fleet becomes a learning system—improvements propagate quickly.

## The Next Stage

- **Scale map:** Pilot Operations → Town services → Regional hubs
- From staples to **strategic industry** (specialty chemicals, inter-settlement trade)
- **Propulsion:** reactors could supply **plasma rocket propellant**
- **Deeper-cheaper:** fuel from Mars to orbit enables further exploration



The rollout is practical: pilot operations grow into town-level services, then regional hubs with real markets. The same reactors can underpin next-tier industry: specialty chemicals and inter-settlement trade.

Methanol from Mars, brought from the surface to the planet's orbit by a Phobos tether, for example, could provide propellant to fuel humanity's exploration into the deeper solar system, unlocking the moons of Jupiter and Saturn.

Foreshadow the big leap: reactors feed propellant precursor streams for plasma engines such as VASIMR and MPD thrusters—all measured, experimental, and powered by standards. Production units on the surface are the source for propellant depots in orbit. The availability of plasma rocket propellant locally produced on Mars means less launch mass from Earth, cheaper deep-space legs, and realistic Mars↔Earth return logistics.

Keep us honest: alongside pilots, run small propulsion-use experiments—power/thrust rigs, materials exposure measurements, and development of plasma engine operating protocols.

Now I'll give you back to Dr. Kelly to talk about plasma rockets.

## Plasma Rockets

### “Muscle Cars” of Space

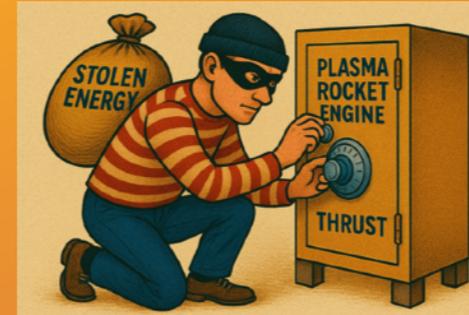
- Versatile: “nurse” the throttle or “floor it”
- Persistent: thrust for long periods, useful for “deep-space” missions
- Durable: few moving parts
- Variable specific-impulse magnetoplasma rocket (VASIMR)
- Magnetoplasmadynamic thruster (MPD)
- Requires dedicated source of electric power (50-500 kW, or even multi-megaWatt range)

I'm excited about the future of plasma rockets. They are versatile in the sense they can do long burns at lower power levels or shorter ones at high power. This makes them particularly useful for two applications: exploration and commercialization of the asteroid belt, and longer range missions, such as to Jovian or Saturnian moons. There are currently two types of larger systems suitable for those roles that differ in the way high-temperature plasma is generated. VASIMR, the variable specific-impulse magnetoplasma rocket, is perhaps more appropriately called a helicon thruster. It uses a magnetic nozzle and a helicon, or magnetized, bounded plasma, to expand and accelerate the ions, then uses ion cyclotron resonance heating to supercharge their energy before releasing them to produce thrust. There is no direct contact of engine with plasma. In contrast, MPD thrusters use an electrode to directly charge and ionize plasma gas via Lorentz forces. The electrode component of MPD requires periodic replacement. Both types of plasma rocket have substantial power requirements.

## Plasma Rocket Recipe

Torture stuff, throw it out the back

- Ionize
- Accelerate
- Spit it out at high speed to produce thrust
- Limitations
  - 1: Power needs (up to 500 kW)
  - 2: Energy loss (Bremsstrahlung)



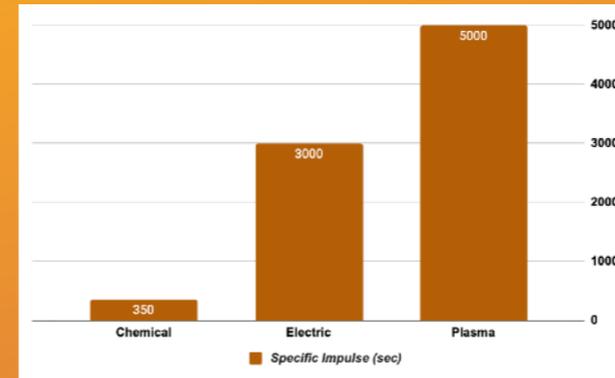
**Bremsstrahlung  
wants your mojo!**

As plasma engines are pushed for more thrust, propulsion energy is lost due to interactions between electrons and nuclei in the plasma. This has a German name, bremsstrahlung, meaning braking radiation. Deceleration of electrons steals thermal energy from the plasma through emission of X-rays. This is called radiative cooling. The amount of loss is influenced by the density and temperature of the plasma, and the degree of charge residing in the nuclei. It is a fact of life for plasma engines, and is more tolerable in steady, low-thrust, economy mode than in performance mode. Think of energy loss in performance mode like the dirty sort of combustion that occurs when you floor the pedal of a muscle car to produce an acceleration spurt. A massive input of fuel, or propellant, in the case of plasma engines, produces more power, but part of it is lost to byproducts—pollutants in the exhaust in the case of muscle cars, Bremsstrahlung energy losses in the case of plasma engines.

Although MPD thrusters operate at lower plasma temperatures, they have much higher plasma densities than are used in engines like VASIMR, so in general, they are more prone to such energy losses.

## VASIMR Plasma (Helicon) Engine

- Few moving parts, limited or no plasma contact (reliability)
- Tolerates wide variety of fuels (usually gas such as H<sub>2</sub>, Xe)
- Ionization of material forms plasma
- Plasma super-accelerated using electromagnetic field



This slide illustrates the relative performance characteristics of three types of rockets. Specific impulse, SI, is a measure of efficiency: how much thrust a rocket can deliver from a given mass of propellant. The chart compares SI for three classes of rocket engines, traditional chemical combustion engines, commonly used electric engines such as Hall thrusters, and Plasma Rockets.

Don't confuse this with thrust, the actual force developed by an operating rocket. Chemical combustion is still the King of Thrust, but the candle burns quickly. Plasma rockets display a versatility that allows them to perform well in fuel-sipping or pedal-to-the-metal situations. At low levels of fuel consumption they show maximum efficiency, ideal for long missions where steady thrust can be used to build up immense speeds. VASIMR has already shown ability to provide a slow, steady thrust for up to four days, and is likely capable of far longer burns.

## Aqueous Methanol as Rocket Propellant an expansion opportunity

- Same readily available inputs: H<sub>2</sub> (from water) and CO<sub>2</sub>
- Store aqueous methanol in delivery modules
- Nebulize methanol/water into a plasma of ionized droplets
- Accelerate the plasma and, **GO!**

Traditionally, VASIMR and MPD have used gaseous propellants. For relatively short missions one might simply use hydrogen obtained by splitting water. But liquids are far more dense. This is perfect for the rocket burns required to make long journeys practical. Consider a mixture of methanol and water. Nebulize that to produce tiny charged droplets, then tease them apart in a partial vacuum and accelerate them to high energy without doing chemistry on the propellant - a crucial factor. Such a process, called electrostatic atomization, is already used on Earth, for applications such as industrial coating sprayers. Thus, experimentation is likely to produce methods for adapting plasma rockets to use liquid propellant instead of gas. That could be a game changer in terms of utilizing them as engines for long-range missions.

## Summary / Conclusions

- Methanol production: keystone to launching a Mars settlement
  - Food source
  - Power utilization and storage resource
  - Mechanical/electrical/engineering nexus
- Expansion opportunities ensure a profitable long-term venture
  - Chemical industry intermediates/targets
  - Plasma rocket propellant source

In summary, production of methanol will be key to establishing a thriving economy on Mars. Many useful features will derive from such an operation, such as basic food ingredients, energy storage and delivery appliances, and development of local engineering expertise. In the longer view, it also supports establishment of chemical industry on Mars, and the availability of locally produced rocket propellant for further exploration and development.

## Drivers for Space Exploration

### Three-legged Stool

- Scientific curiosity
- Geopolitical concerns (national “footprint”)
- Commercial resource harvesting and production



**What happens if one leg outpaces the other two?**



Broadly, there are three reasons for space exploration. Think of them as three legs of a stool. When one is too long compared to the other two, the stool becomes unstable. A profitable methanol business depends on having a colony large enough to absorb the products created. The best chance of success comes when all three motives operate in synchrony. The QR code on this slide links to a short story that describes establishment of a methanol business on Mars in a less balanced situation.

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Thanks for listening. If you have questions or comments later, here is contact info for the authors. I think we have time for some questions now (a very good Q&A session ensued).