

In-situ resource utilization

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The use of local resources is called **in-situ resource utilization** or ISRU. This concept is critical to the survival of an autonomous or semi-autonomous settlement. The ISRU timeline is very rapid for most settlement plans since the initial Zubrin proposal of Mars Direct.

Resources(inputs) are processed to create products(outputs). These outputs can become inputs to other processes used to create new, more complex outputs. Eventually, the outputs can be re-used by recycling, reducing the needs for new resources. However, losses are always present in systems, making the acquisition of new resources a continuous requirement. The presence of numerous resources on Mars is part of what makes it an interesting target for colonization and settlement.

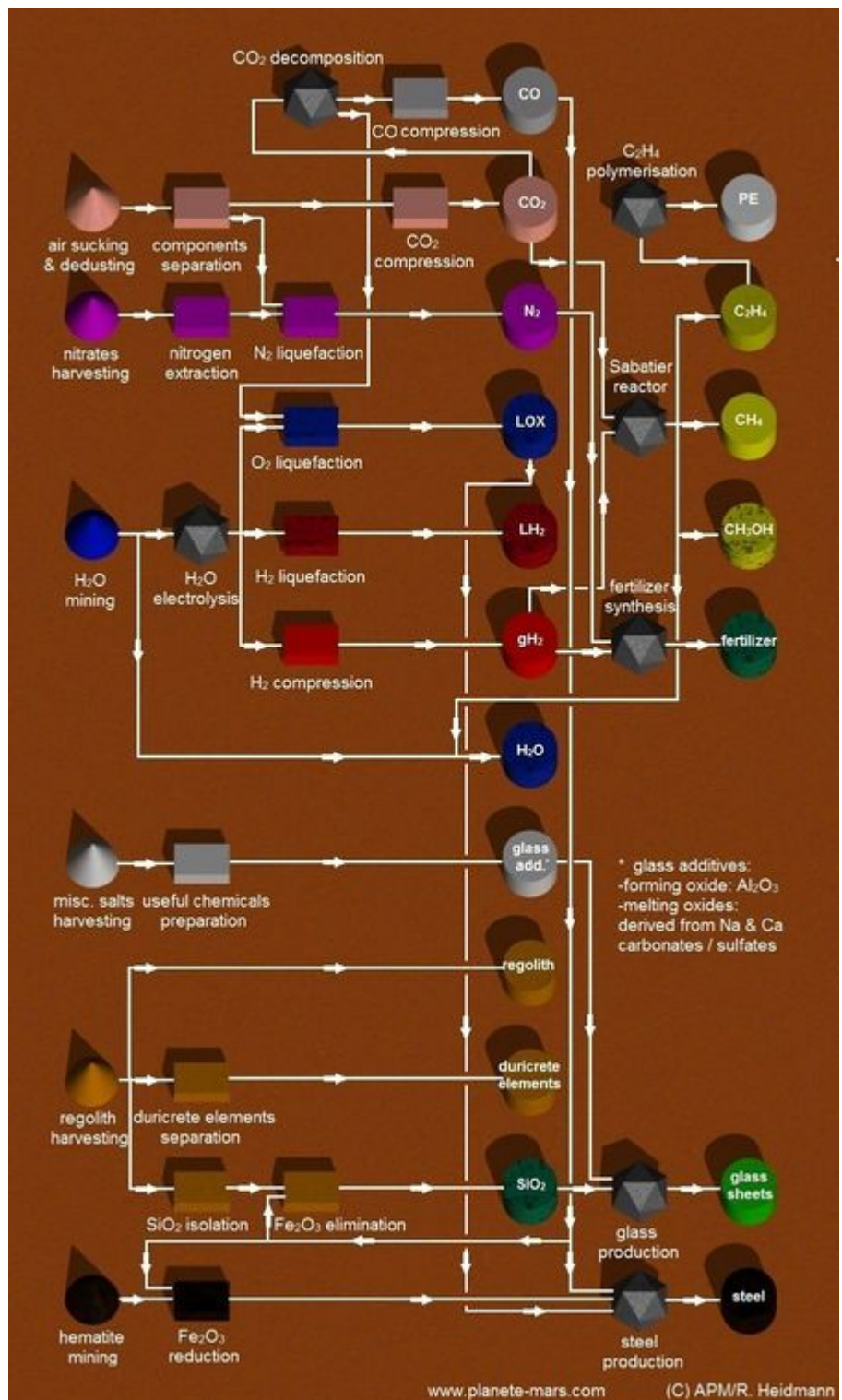
Production processes require energy to operate and must be housed in production facilities.

Resources (Inputs)

Atmosphere

Main article: Atmospheric processing

Many of the elements and molecules in the atmosphere can be utilized. Condensation, followed by distillation, are often used to extract resources. The atmosphere is first cooled to a liquid or solid state. This is distilled at precise temperatures in order to separate the elements and molecules.



In Situ resources Utilisation. Copyright R. Heidmann

- Carbon dioxide (CO₂) composes 96% of the martian atmosphere. Carbon dioxide is the main source of carbon, used for fuel production (CH₄)

and an essential element for life. Carbon dioxide also serves as a source of oxygen for the settlement atmosphere and as the oxidizer in bi-propellant fuels.

- Nitrogen composes 2% of martian atmosphere. Nitrogen is used by plants and is part of a breathable atmosphere. Its concentration on Earth is 78% of the atmosphere.
- Argon is an inert gas, useful in some industrial processes as an inert atmosphere and may be used as propellant in Electric Propulsion of spaceships. 2% of martian atmosphere
- Water (H₂O) is the main source of hydrogen and oxygen. Oxygen is required for the settlement atmosphere and hydrogen is used for fuel production (CH₄) and for the synthesis of hydrocarbons, the building blocks for life.

Lithosphere (surface)

Main article: Mining

Minerals in the crust of Mars must be mined and processed to be useful. The upper layer of Mars surface is called the Regolith. It is a mixtures of materials of various interest.

- Water can be gathered in a variety of ways. It is available in the form of water ice or as hydrated minerals.
- Silicates (SiO₂) are useful for the production of glass and building materials. It is one of the main components of the martian planetary crust.
- Iron ore (Hematite:Fe₂O₃) or (Magnetite: Fe₃O₄) is a source of iron and steel, as well as oxygen or CO₂, depending on the process used.
- Alumina (Al₂O₃) is the source of aluminium. Processing also produces CO₂, oxygen or water, depending on the process used.
- Calcium carbonate (CaCO₃) is used for concrete production. Carbonates are also a potential source of carbon for carbohydrates. Sodium carbonates are used in glass production. Carbonates are available on Mars.^[1]
- Sulfates
- Nitrates are sources of nitrogen for plants and industrial processes, ammonia and explosives. Nitrates were discovered on Mars by the Curiosity rover in 2015.
- Salts. (Mg,Na)SO₄, NaCl, and (Mg,Ca)CO₃. Magnesium, Calcium, Sodium, lithium, Chlorine. Practically all minerals and elements can be found in the form of salts. Sodium chloride (NaCl) is the most common salt, and is essential for life. Chlorides are likely to be abundant on Mars.^[2]
- Thorium (Th) concentrations have been identified by JPL on Mars, this is the preferred fuel in a number of Molten Salt Reactor designs. ^[3]

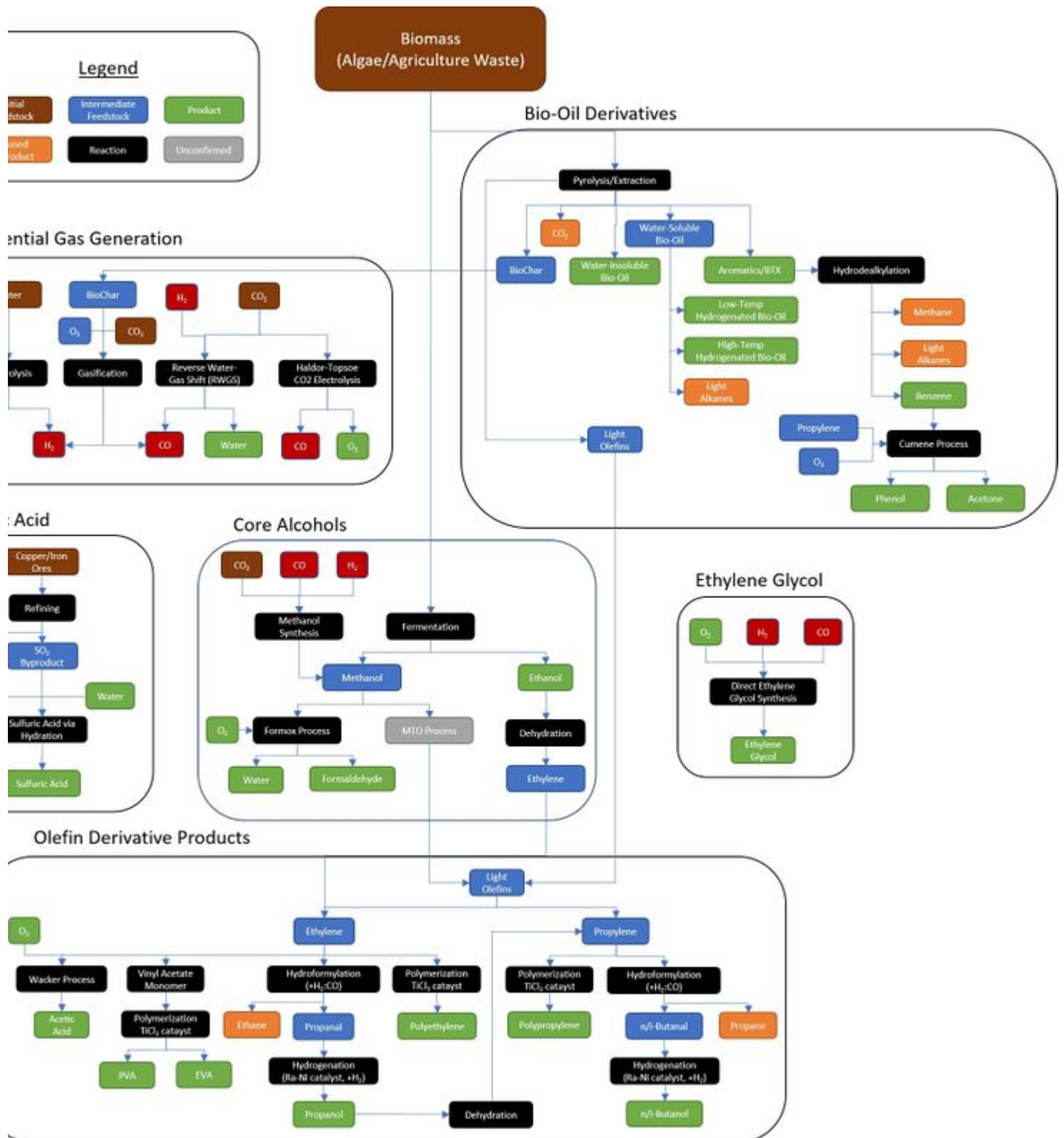
Energy

Main article: Energy

Energy is required to carry out ISRU. There are three known sources of energy on Mars: the Sun, Mars' crust and nuclear fission. Energy may be stored in a variety of ways for when the sources are not available.

- Solar energy is a very variable energy source on Mars, unless some form Space Solar energy is used. It requires some form of energy storage in the settlement or supplementary energy sources, most likely nuclear.
- Nuclear energy is a stable energy source and could be used extensively on Mars. The availability of nuclear fuel on Mars needs to be explored and usable ore deposits found for a self sustainable settlement.
- Geothermal energy may be available in some martian sites.

Processes



Source: Rider Barnum, Anna

Inputs need to be processed to create outputs

Mechanical processes

- Compression of gases increases their density and can change conditions to allow for phase changes that can be used for gas separation.
- Heating and cooling can also be used to accomplish phase changes in various substances.
- Crushing and milling. These are mechanical processes that break minerals down to individual crystals for separation and materials handling. Complex minerals such as basalts, granites or ores can be broken down for separation
- Separation Mechanical, centrifugal,
- Flotation,
- Distillation,
- Condensation

Chemical processes

Gases

- Gasification
- Reverse Water-Gas Shift Reaction
- Haldor Topsoe CO₂ electrolysis
- Sabatier/Water Electrolysis Process
- Fischer-Tropsch Reaction
- Electrolysis

Alcools

- Methanol synthesis
- Formox process. For the production of Formaldehyde
- MTO process
- Dehydration

Bio-oil derivatives

- Pyrolysis/extraction
- Hydrodealkylation
- Cumene process

Olefin derivatives

- Wacker process
- Vinyl acetate monomer
- Polymerization
- Hydroformylation
- Hydrogenation

Direct ethylene glycol synthesis

Hydrocarbon synthesis

Hydrocarbons can be manufactured by combining and carbon through a variety of reactions

Silicone Synthesis

Reduction

Usually, but not exclusively, of a compound into individual elements. Iron ore into iron and oxygen, for example.

Biological processes

- Fermentation
- Biomethanisation

Products (Outputs)

Liquids

- Water. Essential for life. It is also a common process reagent, an excellent coolant for industrial processes and a source of hydrogen and oxygen using electrolysis. On Mars it can also be used as a construction material or as radiation shielding. It can be condensed out of the atmosphere or extracted from the regolith.
- Ammonia
- Hydrocarbons
 - - Light olefins
 - Light alkenes
 - Benzenes
 - Phenol
 - Acetone
 - Bio-oil
- Alcohols
 - Ethanol
 - Methanol
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Gases

A breathable atmosphere is a basic requirement for life. It is also needed for heat transfer from people, plants and animals. It is obtained from compression of the martian atmosphere, separation of excess CO₂ and addition of oxygen to reach the desired proportions, that depend on the chosen atmospheric pressure in the habitats.

- Oxygen (O₂)
- hydrogen (H₂)
- Nitrogen (N₂)
- Argon (Ar)
- Carbon dioxide (CO₂)
- Carbon monoxide CO
- Hydrocarbons
 - Methane (CH₄) Propellant when combined with oxygen. Propellant is one of the main ISRU products. It is required to make transportation less prohibitively expensive.
 - Ethylene
 - Propylene
 - Propane
 - Butane

- Formaldehyde

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Solids

- Fertilizer (N....)
- Biochar (Cx)
- Synthetic Polymers and carbon fiber precursors
 - Polyethylene
 - Polypropylene
 - Polyester
 - Poly vinyl chloride (PVC)
 - Polyamides (Nylon)
 - Polytetrafluoroethylene (PTFE, Teflon)
- Sand is one of the most common building materials. Composition varies greatly.
- Gravel
- Cement is a binder used to link together elements such as blocks and bricks or gravel and sand to produce concrete.
- Concrete
- Compressed regolith
- Glass is one of the most common building materials on Earth and should be common on Mars as well, since it has unique properties of low cost and transparency. Silica (SiO₂), the main component of glass, is also the most common material in the Martian crust.
- Ceramics
- Biomass
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Metals

- Iron
- steel
- Aluminium
- Copper
- Nickel
- Silicon

References

1. Wikipedia Carbonates on Mars[1] (https://en.wikipedia.org/wiki/Carbonates_on_Mars)
2. Wikipedia- Chlorides on Mars[2] (https://en.wikipedia.org/wiki/Chloride-bearing_deposits_on_Mars)
3. Map of Martian Thorium at Mid-Latitudes, JPL *Map of Martian Thorium at Mid-Latitudes* , <https://www.jpl.nasa.gov/spaceimages/details.php?id=PIA04257>, March 2003.

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