The Mareekh Process

A Hybrid Power Generation Concept for Mars Utilizing Subsurface Water Ice and Environmental Exergy

Patent no. US 11421559 B1

Australian Space Research Conference 2026
Adelaide

Dr. Muhammad Akbar Hussain
Co-founder and CEO, Mareekh Dynamics

MAREEKH DYNAMICS
www.mareekh.com

Talk flow

01 **Problem** — Mars needs power and heat; conventional options have constraints.

02 **Resource** — Subsurface water-ice and the cold, low-pressure atmosphere create a thermodynamic opportunity.

03 **Process** — Superheated and supercritical water pathways feed a turbine and recover latent heat.

04 **Numbers** — Preliminary mass/energy balance suggests useful power plus habitat thermal utility.

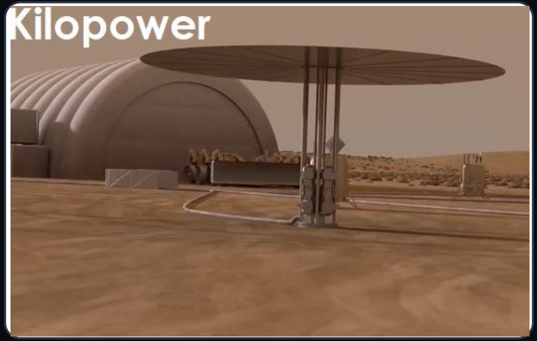
05 **Pathway** — Laboratory validation, Mars-analog tests, then integrated habitat demonstrations.

Mars power: the current baseline

Solar and nuclear remain the practical primary options. Mareekh Process begins where they leave a high-temperature working fluid and a cold, low-pressure sink.

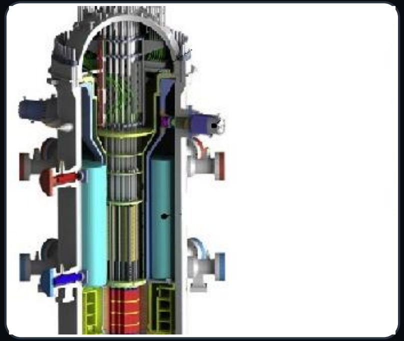
RTG

Reliable but low power density for settlement-scale loads.



Kilopower / fission

Strong candidate for baseload power on early missions.



SMR

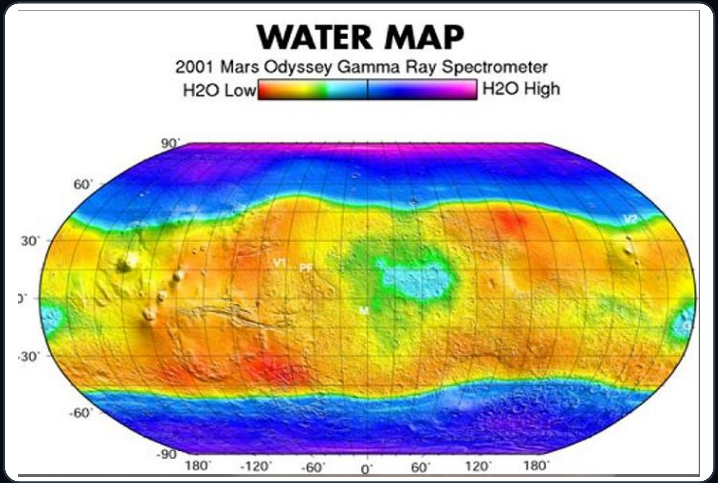
Potential settlement-scale source; high mass and deployment complexity.

Wind / tidal / fossil / geothermal

Limited or non-viable on Mars in present concepts.

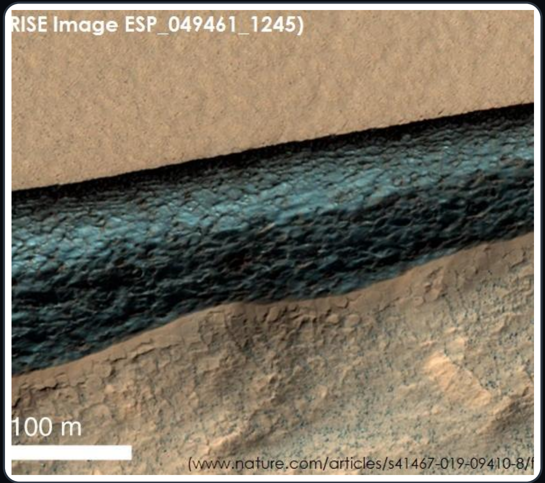
OPPORTUNITY

Mars supplies both feedstock and sink



Covers vast regions on Mars

Fairly close to the surface



Can be several kms in thickness

Thin and cold atmosphere

H_2O

subsurface water-ice as ISRU feedstock

≈−60°C

cold thermal sink

≈0.006 bar

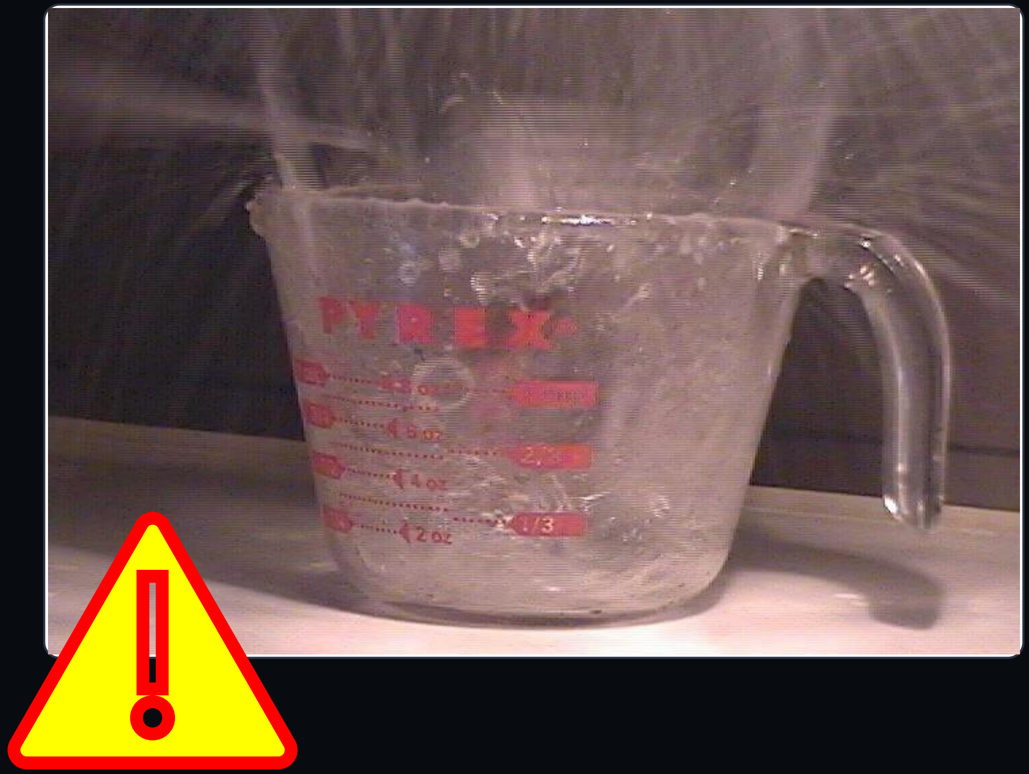
low pressure boundary

high Δp

large expansion ratio

The concept uses subsurface ice as the working mass source and the Martian atmosphere as an unusually cold, low-pressure outlet environment.

Core principle: pressure-triggered flashing



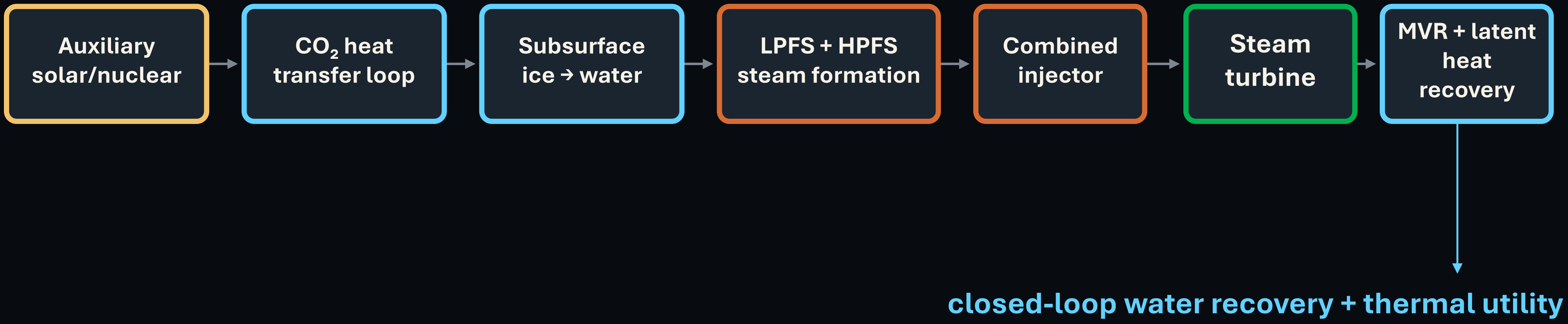
Expose heated water/steam to pressure below its saturation pressure:

- **Superheated water** — thermal energy stored in liquid phase
- **Flash steam** — rapid phase transition when pressure drops
- **Turbine expansion** — pressure/temperature gradient converted to work
- **Condensation** — latent heat recovered for habitat systems

Safety note: the demonstration image illustrates violent flashing. The engineered system would control this inside a sealed pressure path and turbine train.

PROCESS

Simplified system architecture

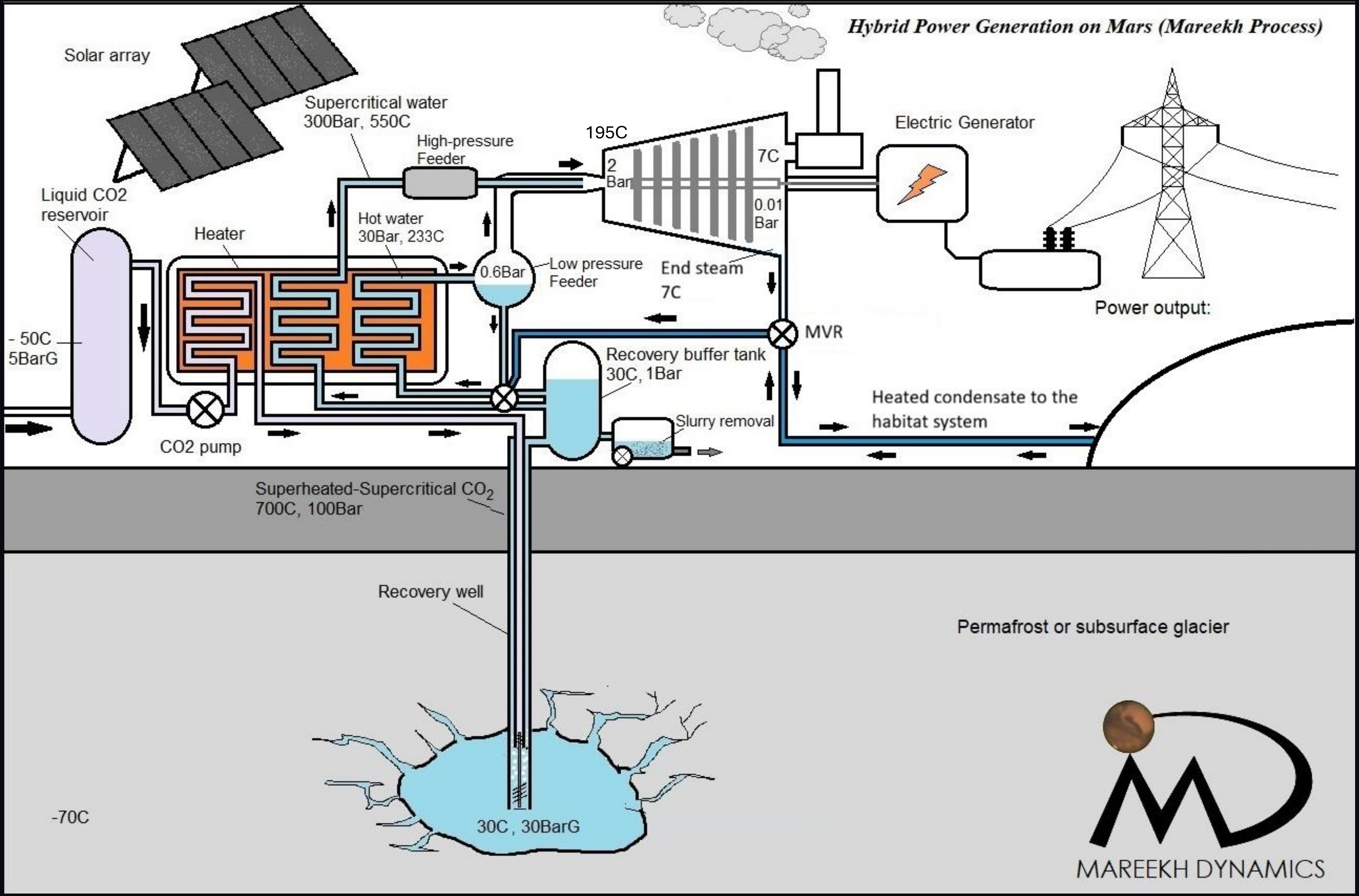


Key design logic

- Auxiliary energy raises water to high enthalpy states.
- Martian ambient pressure acts as the low-pressure boundary for expansion.
- Most end-steam is recovered through mechanical vapour recompression.
- Recovered latent heat becomes habitat thermal utility.

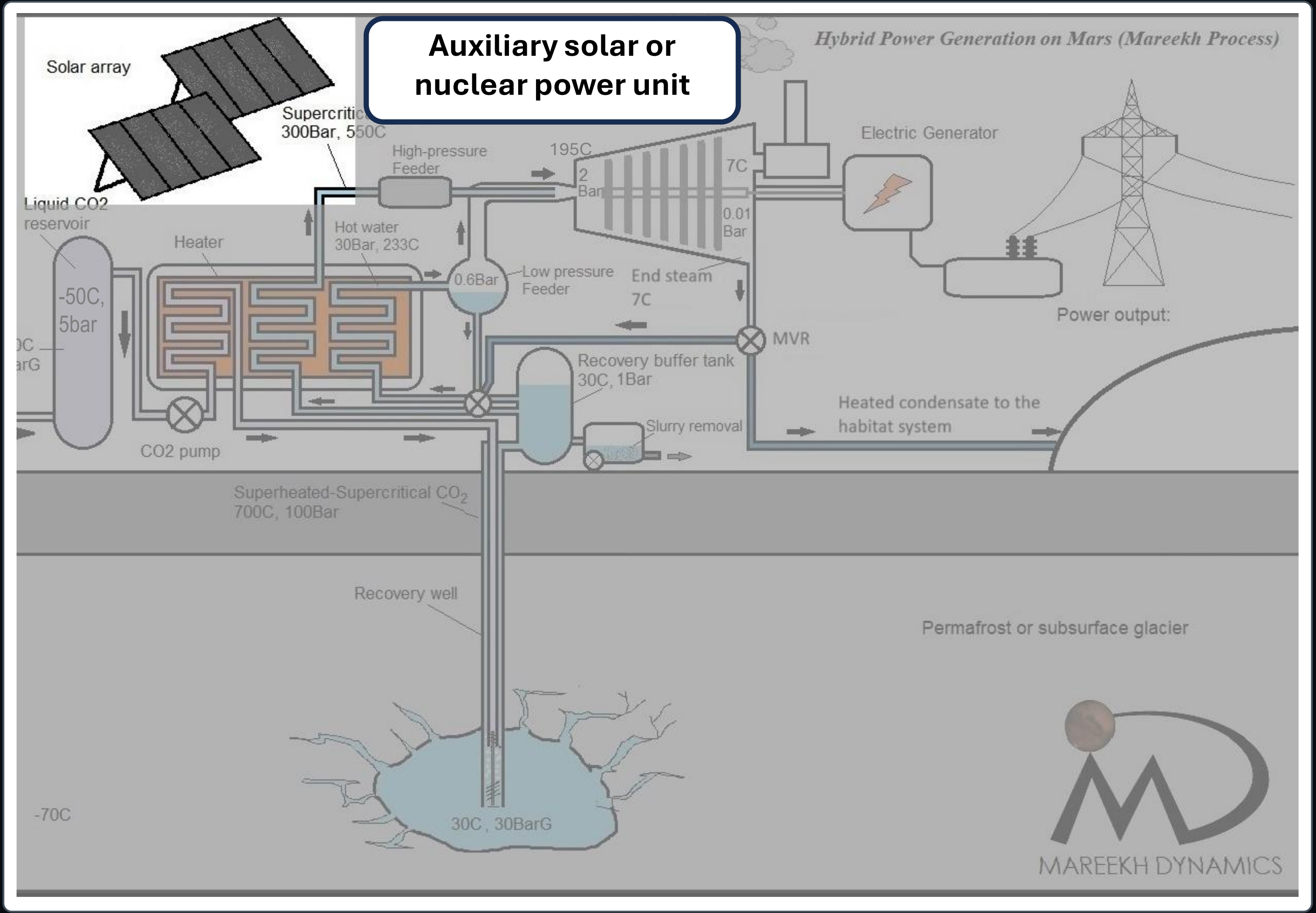
PATENT ARCHITECTURE

Detailed process diagram



PROCESS STEP 1

Auxiliary power raises the working fluid

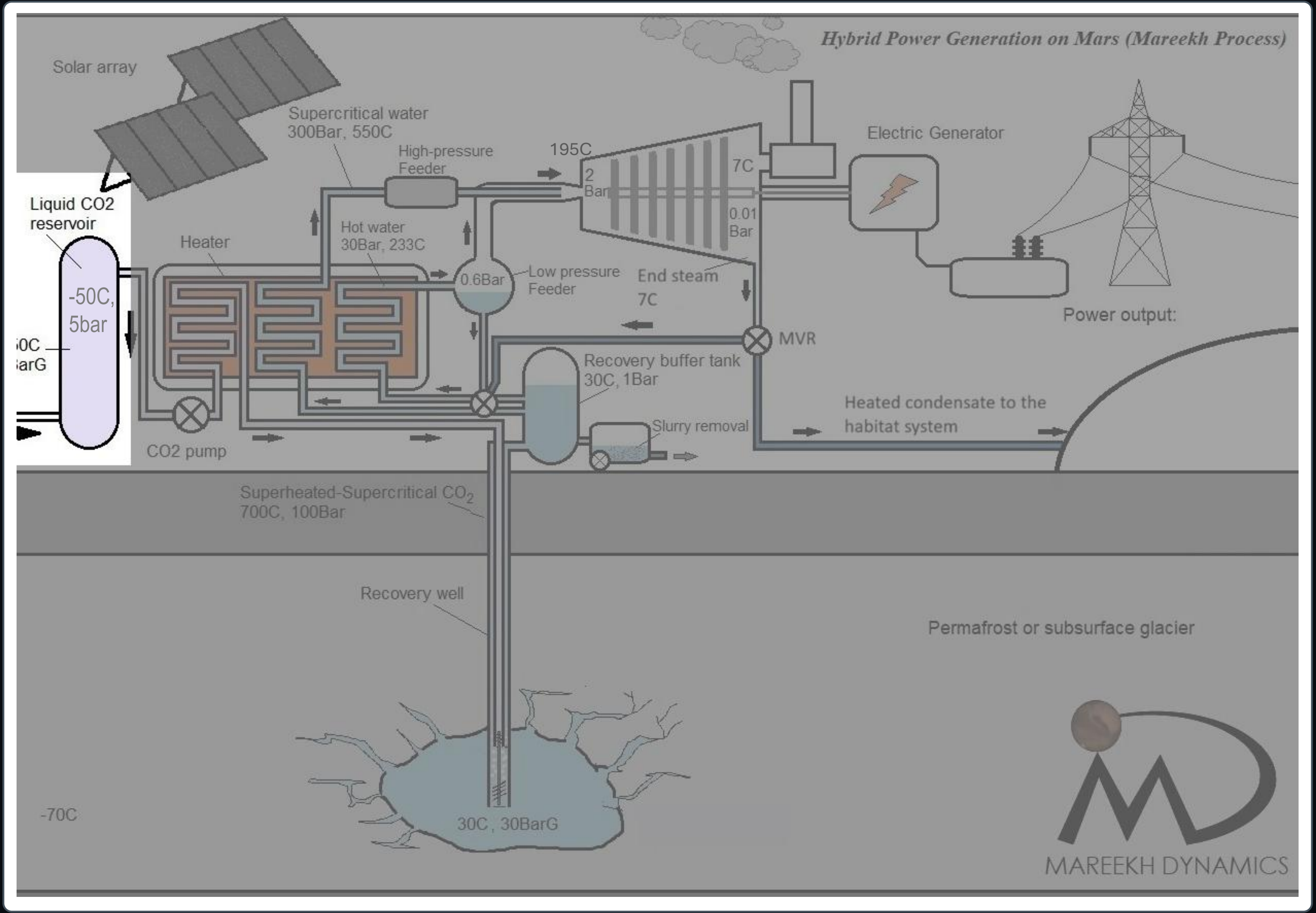


Heat input

- Solar or nuclear unit supplies controlled heat input.
- Purpose is to create high-enthalpy working fluid, not to replace the auxiliary source.
- Hybrid design allows flexibility across mission architecture.

PROCESS STEP 2

CO_2 loop transfers heat into the subsurface

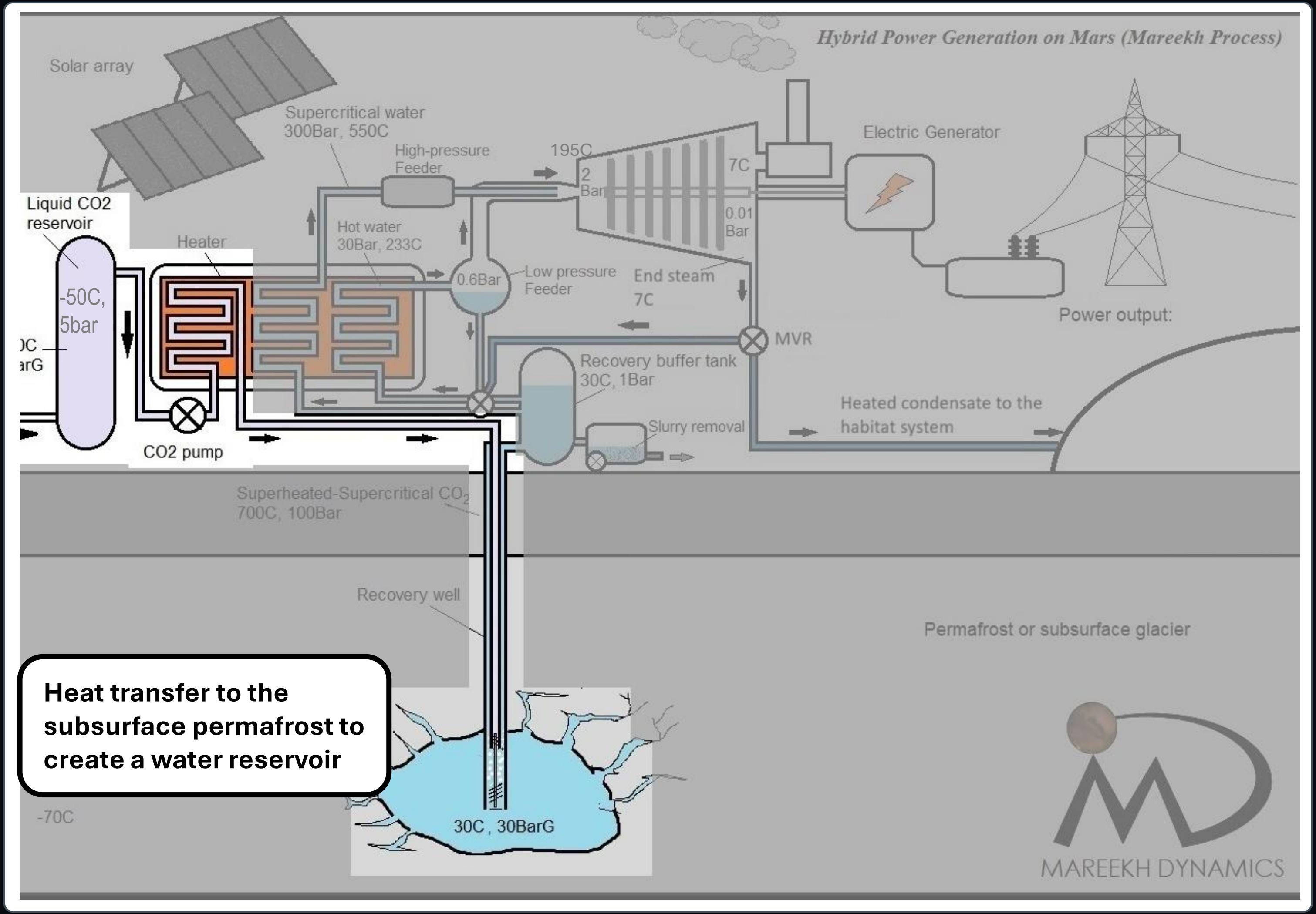


Heat transfer

- CO_2 loop can act as heat-transfer medium to access buried ice.
- Closed loop minimises consumable losses.
- High-temperature duty drives ice melting and reservoir creation.

PROCESS STEP 3

Subsurface reservoir becomes the water source

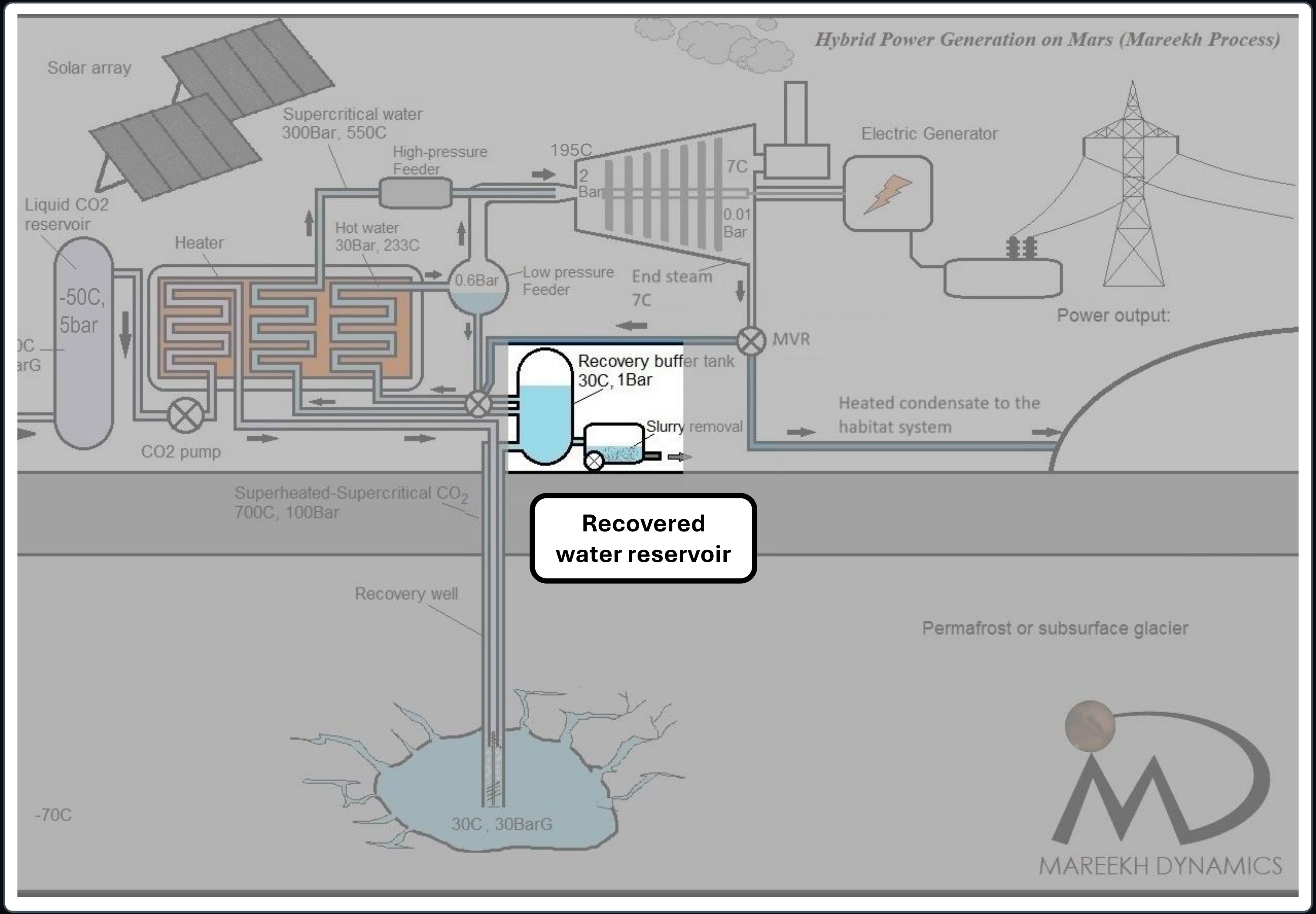


Water source

- Target: permafrost or subsurface glacier.
- Injected heat creates a recoverable water reservoir.
- Recovery path also has to manage slurry and particulates.

PROCESS STEP 4

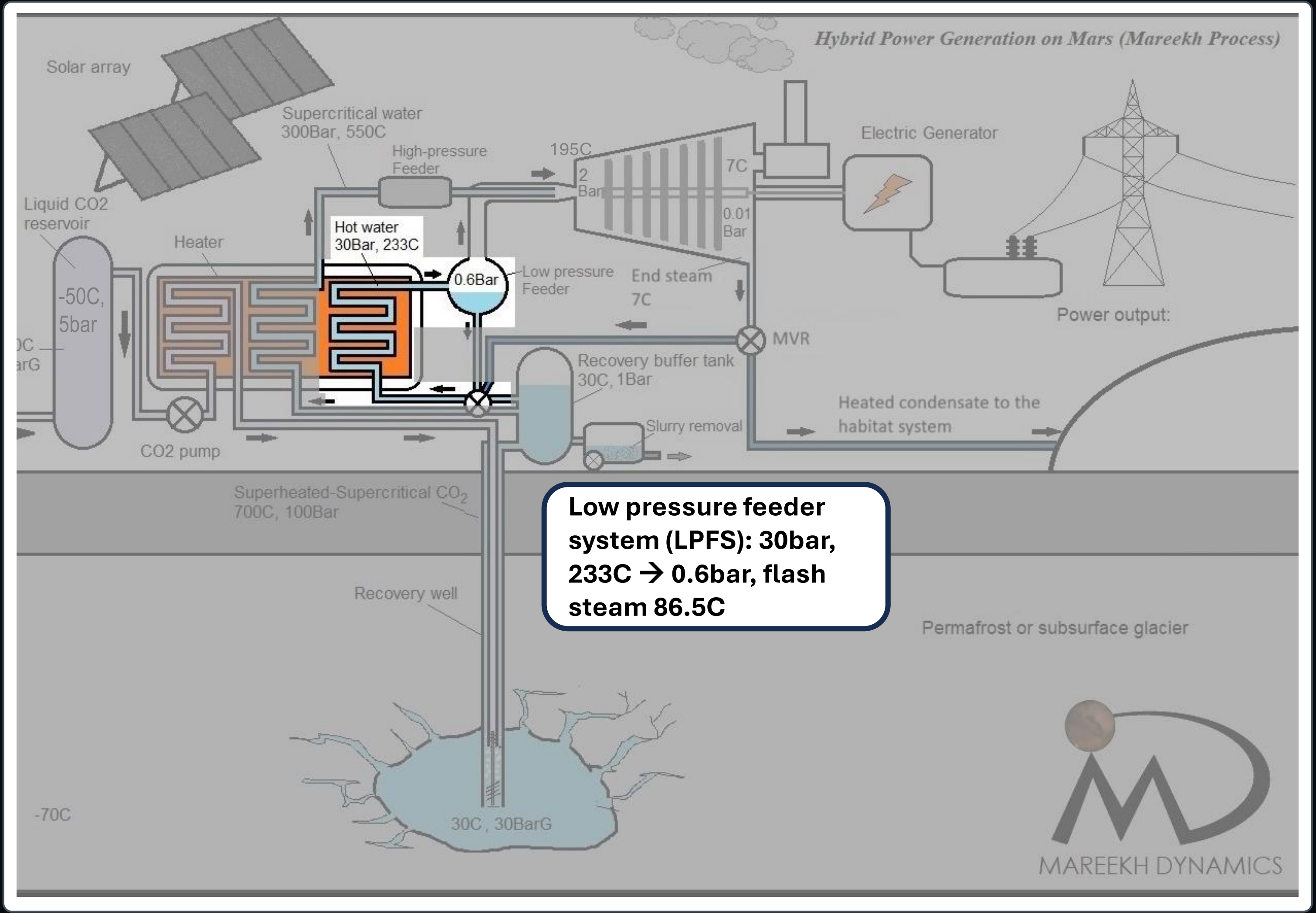
Recovered water is conditioned and buffered



Recovery

- Recovered water enters a buffer tank.
- Slurry removal is an explicit process requirement.
- Water is then divided into LPFS and HPFS pathways.

LPFS creates flash steam

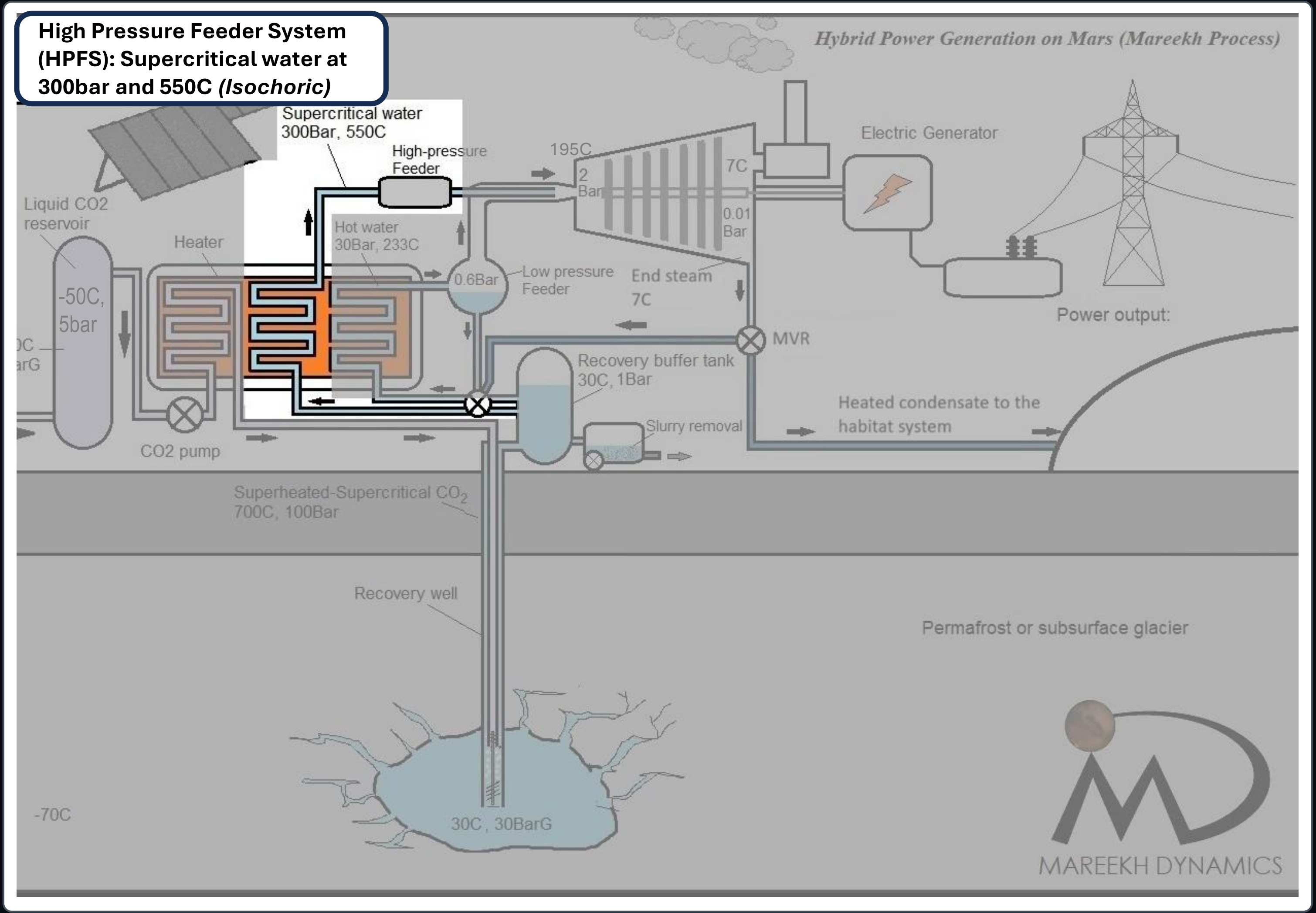


LPFS

- Representative path: 30 bar, 233°C → 0.6 bar 86.6C flash steam (flash steam fraction 28.6%).
- Flash fraction and steam quality are key validation parameters.
- LPFS contributes saturated/flash steam to the combined injector.

PROCESS STEP 5B

HPFS creates a supercritical/superheated contribution

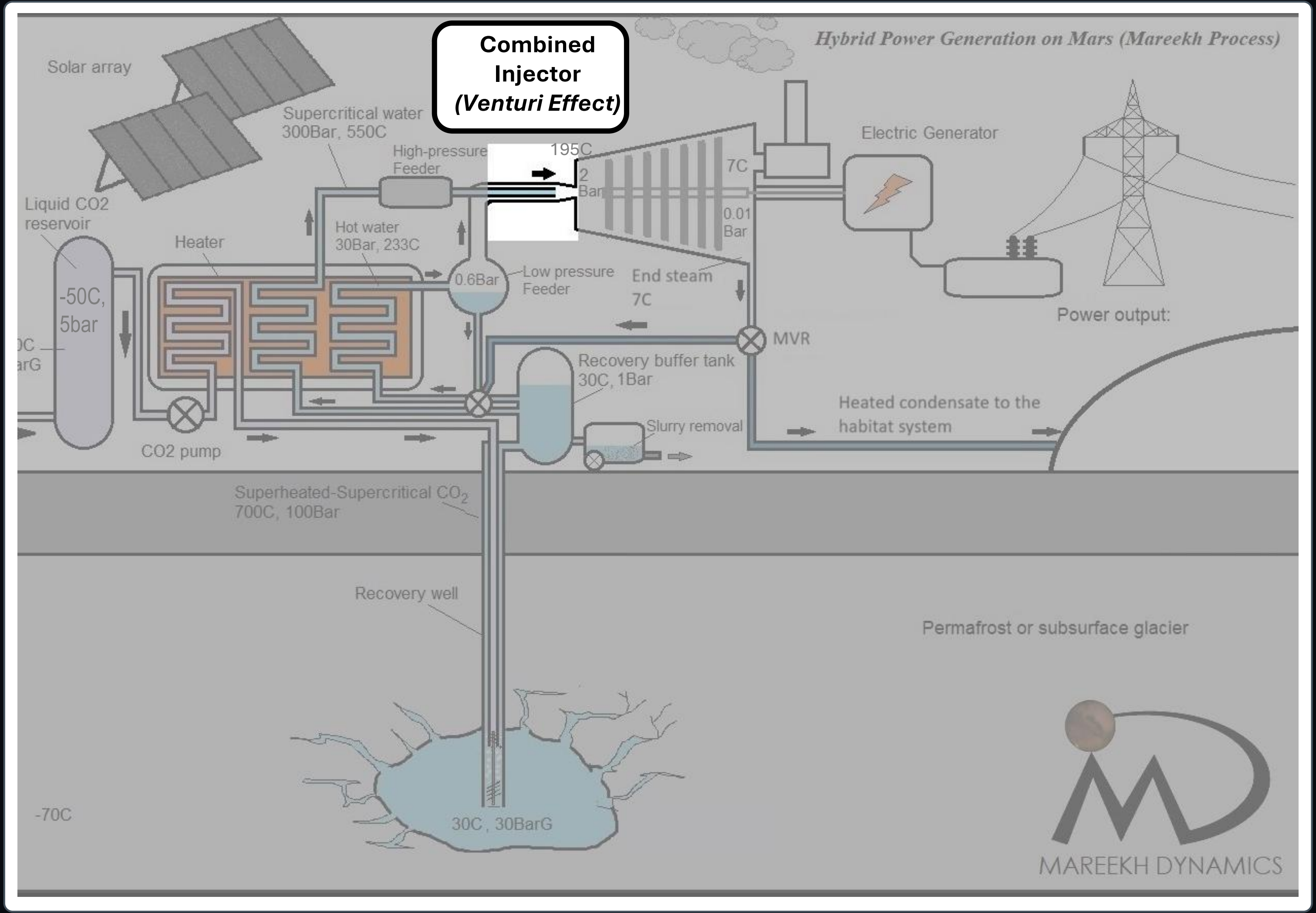


HPFS

- Representative condition: 300 bar and 550°C.
- Supercritical water is used to convert the LPFS saturated steam into superheated steam.
- HPFS contributes a high-enthalpy component to the steam mix and contribute to its bulk.

PROCESS STEP 6

Combined injector feeds the turbine

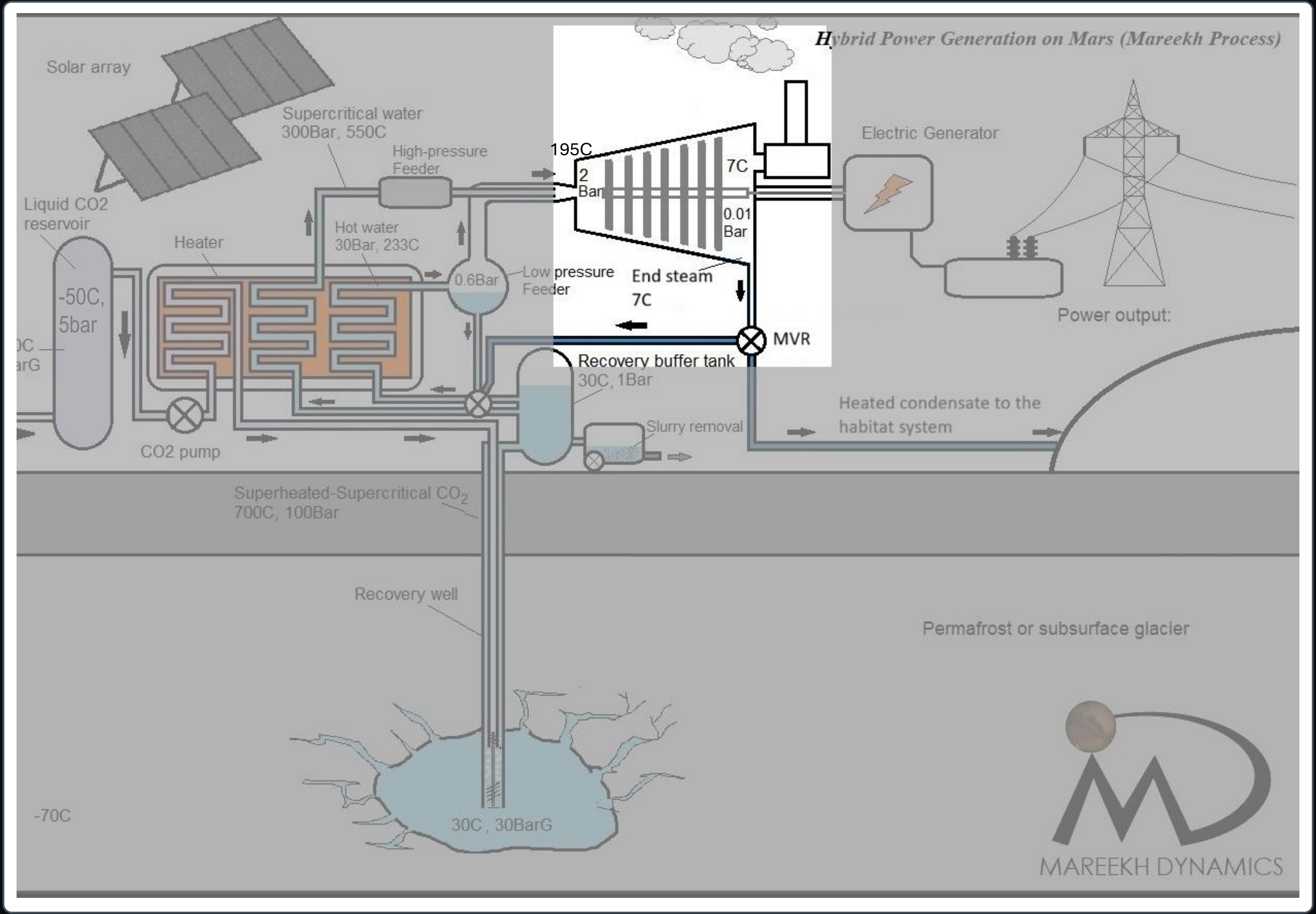


Injector

- Venturi effect from the flashing supercritical water to propel the steam mixture forward.
- Target turbine inlet in the deck: ~2 bar, ~195°C.
- Injector design controls flow stability and steam quality.

PROCESS STEP 7

Turbine exhaust enters a very low-pressure sink



Turbine

- Back-end interfaces with Mars-like low pressure using pressure control valve open to the exterior.
- A small fraction may be vented; majority is recovered.
- Sacrificing a fraction of end-steam helps keep the back-turbine at low pressures and end-steam at near-saturation conditions.

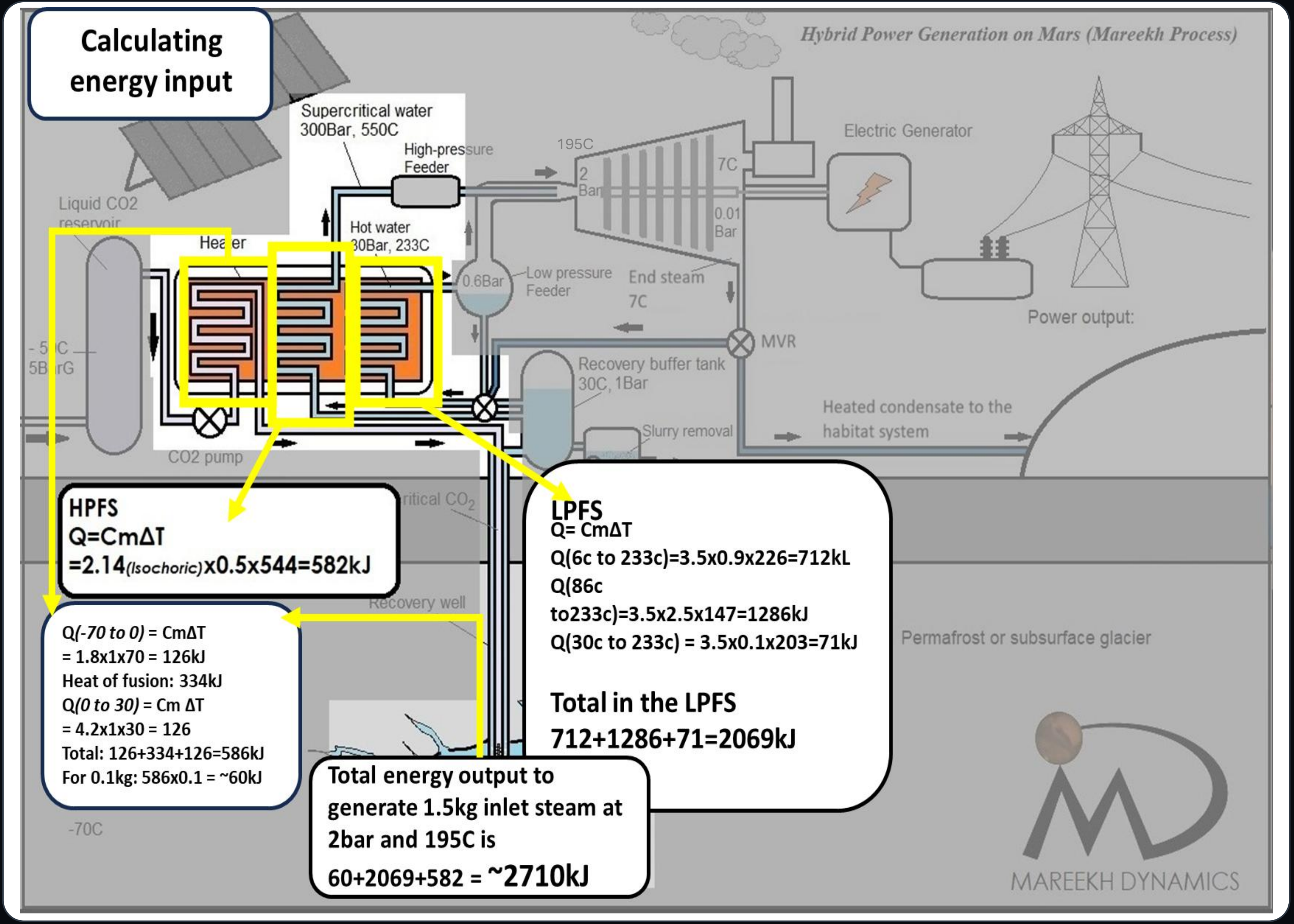
Illustrative operating points

Subsystem	Reference condition used
CO_2 heat-transfer loop	−50°C, 5 barG → superheated/supercritical CO_2 at ~700°C, 100 bar
Recovered water buffer	~30°C, 1 bar
LPFS water path	30 bar, 233°C → 0.6 bar flash steam at ~86.5°C
HPFS water path	300 bar, 550°C supercritical water; isochoric heating assumption
Turbine inlet	mixed steam to turbine: ~2 bar, ~195°C
Turbine exhaust / sink	~0.01 bar, ~7°C; small vent fraction, majority recovered by MVR

ILLUSTRATIVE CALCULATION

Energy input budget

Melt + warm ice	~60 kJ	0.1 kg equivalent from −70°C to 30°C, including fusion
HPFS heating	~582 kJ	0.5 kg water heated isochorically under 300 Bar to form supercritical water at 550°C
LPFS heating	~2,069 kJ	3.5kg water from condensate recovery, flash tank, and buffer tank is heated to 233°C under 30 Bar to form flash-steam feed
Total auxiliary heat input	~2,710 kJ	cumulative energy input for the formation of 1.5kg superheated inlet steam



ILLUSTRATIVE CALCULATION

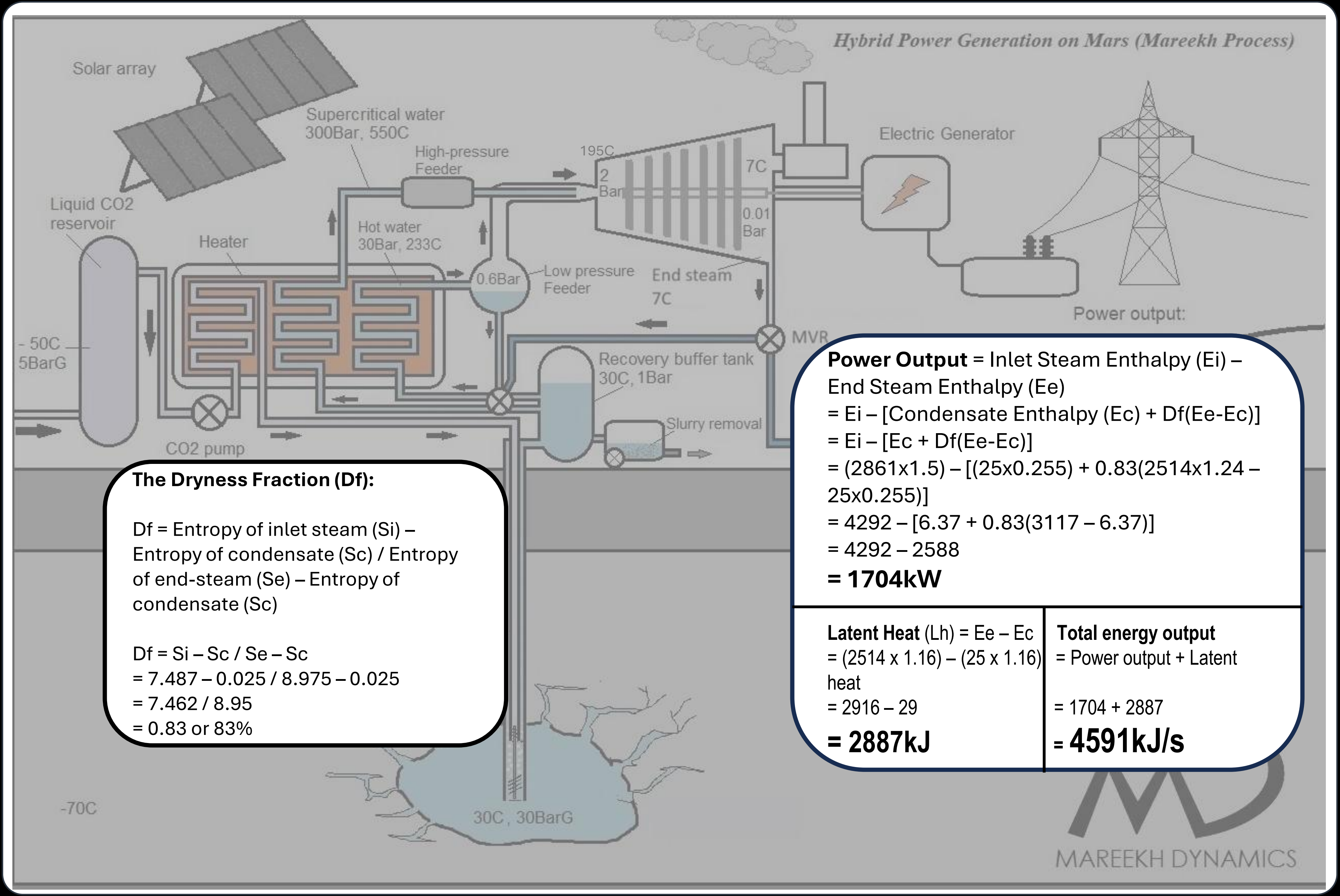
Energy output

~0.83
Dryness fraction

~1,704 kJ
Turbine work

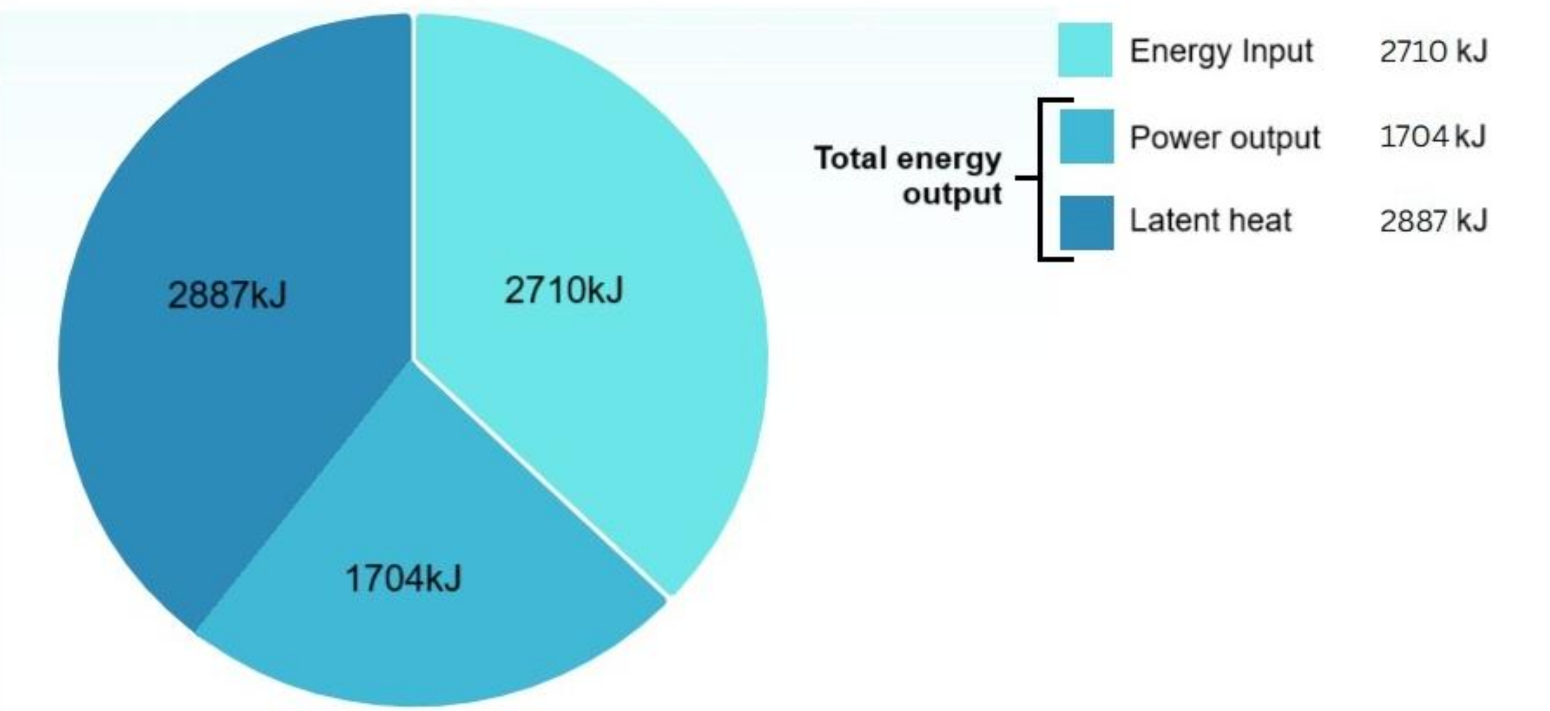
~2,887 kJ
Recovered latent heat

~4,591 kJ
Useful output



Useful output: work plus thermal utility

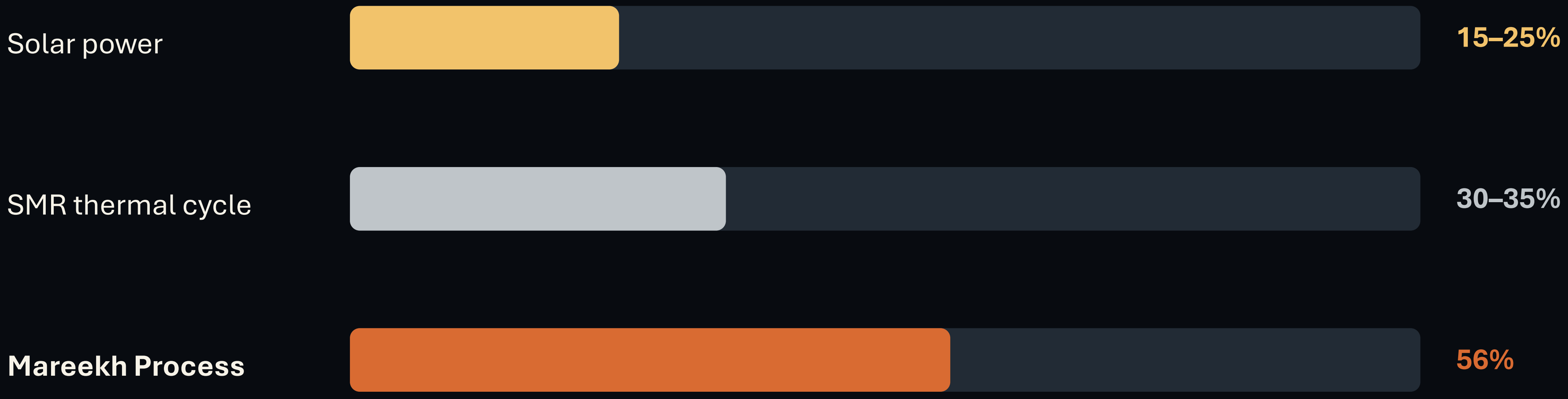
Comparison of the energy input and the total energy output including power output and the latent heat through formation and utilization of 1.5kg/s superheated steam at 195c under 2 bar pressure with 0.1kg recycling



The value proposition is not only electricity. Capturing latent heat converts the exhaust path into a habitat thermal-management asset.

PRELIMINARY ESTIMATE

Mechanical efficiency comparison



A modelling target and validation hypothesis until a closed-loop prototype is tested.

DIFFERENTIATION

What makes it Mars-specific?

Low ambient pressure

Naturally supplies a deep expansion boundary for flash and end-steam.

Cold environment

Improves sink temperature and supports condensation duty.

Water-ice abundance

Provides an in-situ working fluid source near candidate settlement regions.

Thermal utility value

Waste heat is useful, not a nuisance, in a habitat context.

On Earth, the same boundary conditions are expensive to create. On Mars, they are ambient.

DIFFERENTIATION

The inherent Martian advantage

Enhanced Exergy Potential

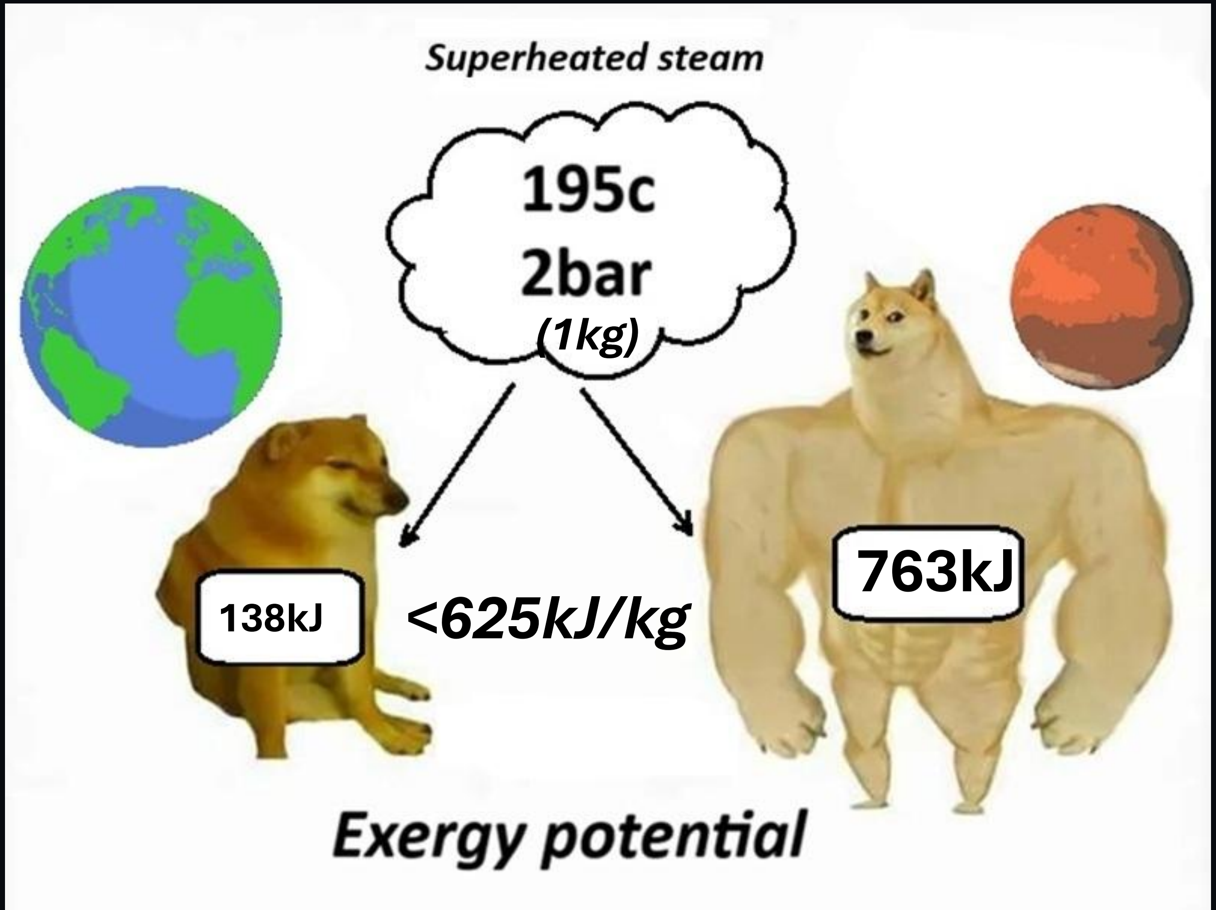
Superheated steam in Martian planetary conditions carry much higher exergy potential than on Earth

A deep thermodynamic sink

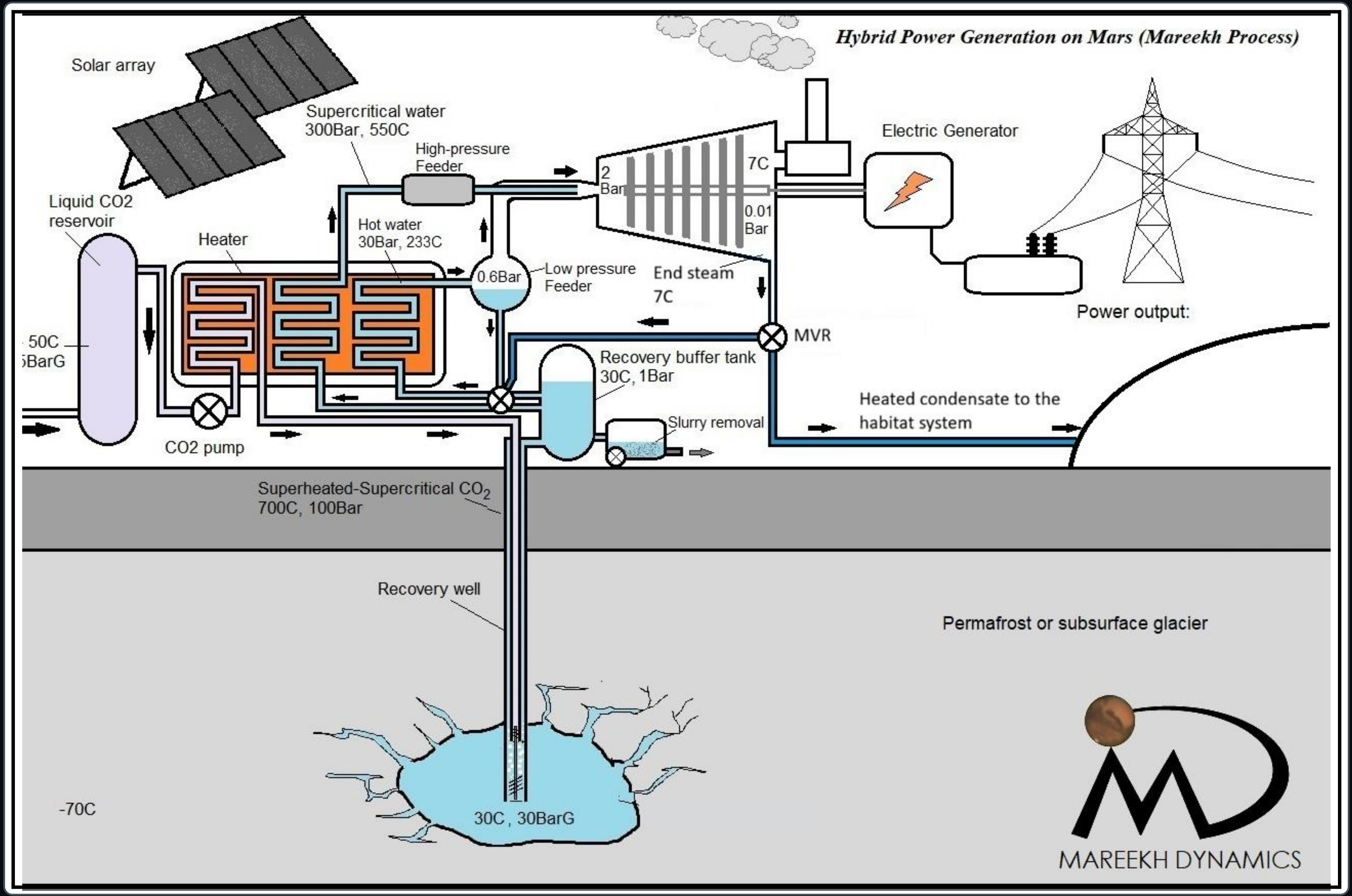
The cold and thin Martian atmosphere creates a perfect environment for maximum steam expansion and work extraction.

An ancient entropy imbalance/debt

The trapped subsurface liquid water froze solid instead of sublimating as Mars lost its atmosphere billions of years ago.



Integration with a Mars habitat

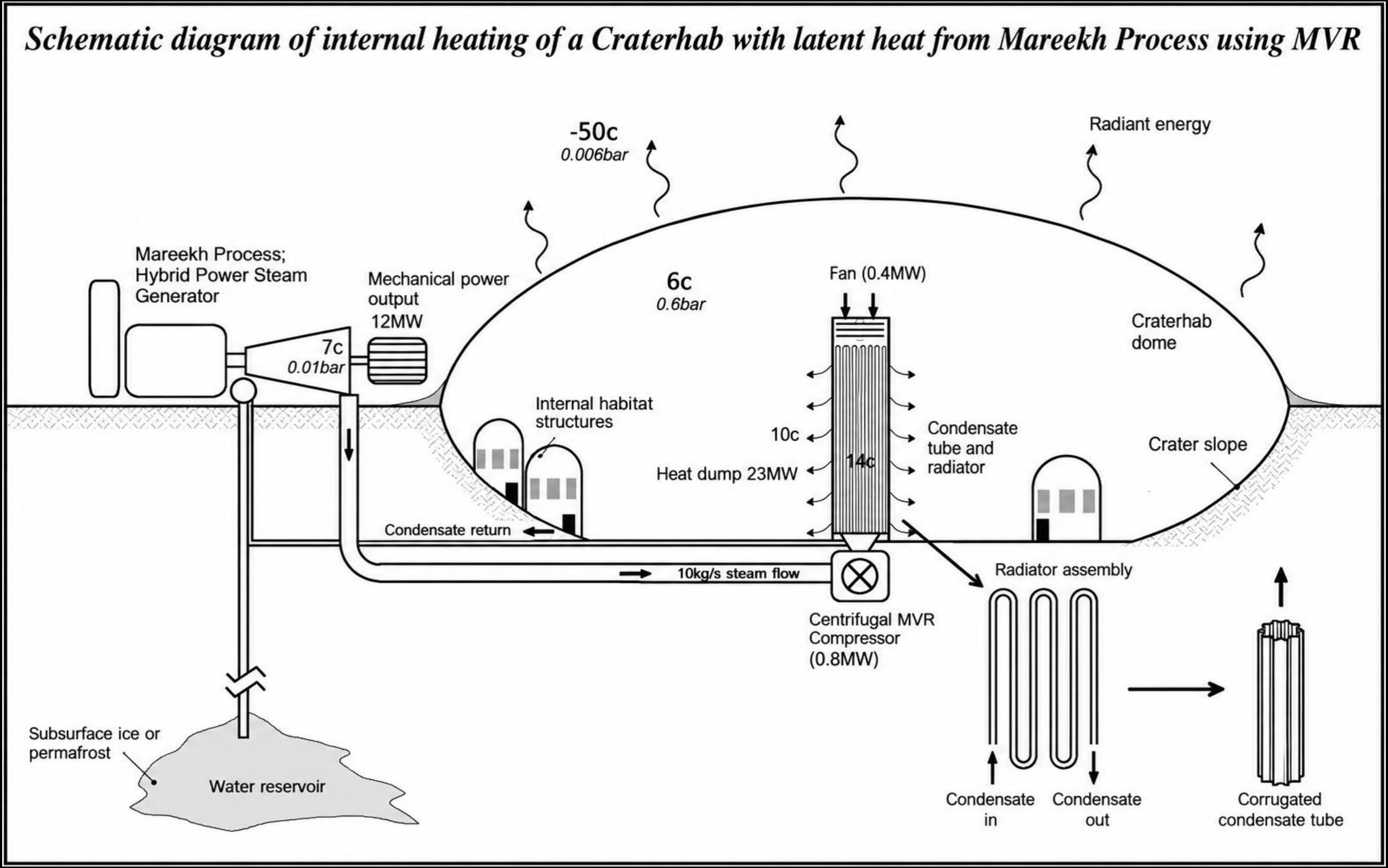


Habitat thermal bus

Recovered condensate heat
→ air + water loops
→ process preheating

Design aim: use the turbine exhaust path as a dual-service subsystem; power generation first, thermal recovery second.

Habitat heating



TECHNICAL RISK

Critical engineering challenges

Two-phase turbine tolerance

steam quality, droplet erosion, nozzle geometry

CO_2 loop materials

700°C thermal cycling, sealing, pump durability

Ice reservoir dynamics

thermal plume, collapse, refreeze, brine/slurry handling

MVR power draw

net cycle benefit after compression work

Dust and fouling

heat exchanger degradation, filters, maintenance

System mass

launch mass, spares, redundancy and safety margins

CONCLUSION

Bottom line

The Mareekh Process proposes a Mars-native way to combine power generation and thermal utility.

ISRU feedstock — Subsurface water-ice becomes the working mass

Environmental exergy — Low pressure and cold ambient conditions act as sink

Hybrid architecture — Solar/nuclear heat is transformed into work and useful heat

Settlement relevance — Thermal recovery directly supports habitat operations

REFERENCES

Selected resources

- US Patent and Trademark Office. Patent Public Search. US Patent No. 11,421,559 B1.
- Steam and water thermodynamic properties: University of Wisconsin IRC; HSZG thermo calculators.
- Flash steam calculator: SimuPipe tools.
- Steam turbine calculation resources: DOE steam tools; CodeCalculation turbine performance calculator.
- Engineering Thermodynamics — Israel Urieli, Ohio University.
- Mars water-ice and atmosphere imagery: sources noted in the original slide deck.

Note: calculations shown are illustrative concept values for conference discussion, pending experimental validation.