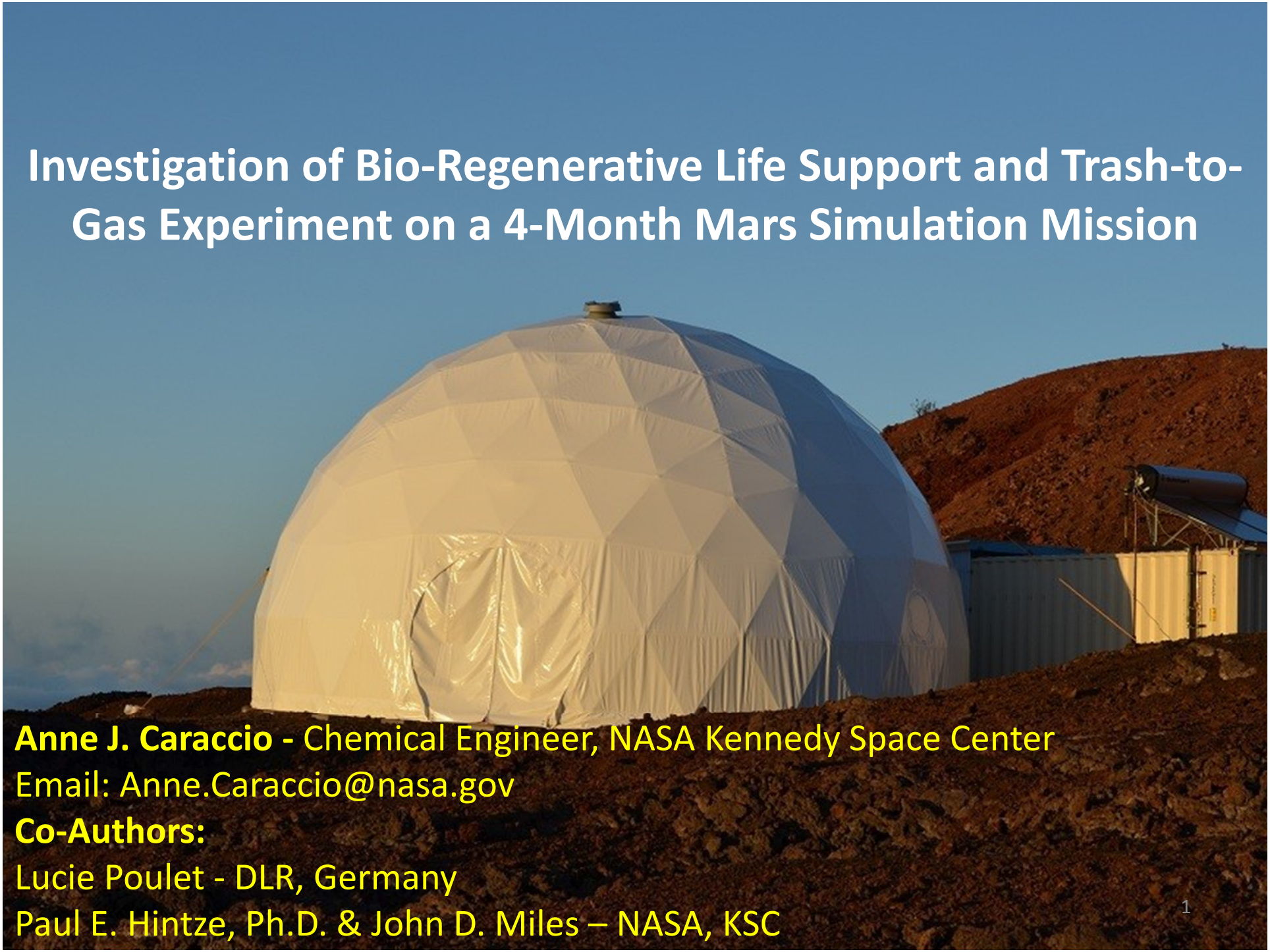
Investigation of Bio-Regenerative Life Support and Trash-to-Gas Experiment on a 4-Month Mars Simulation Mission



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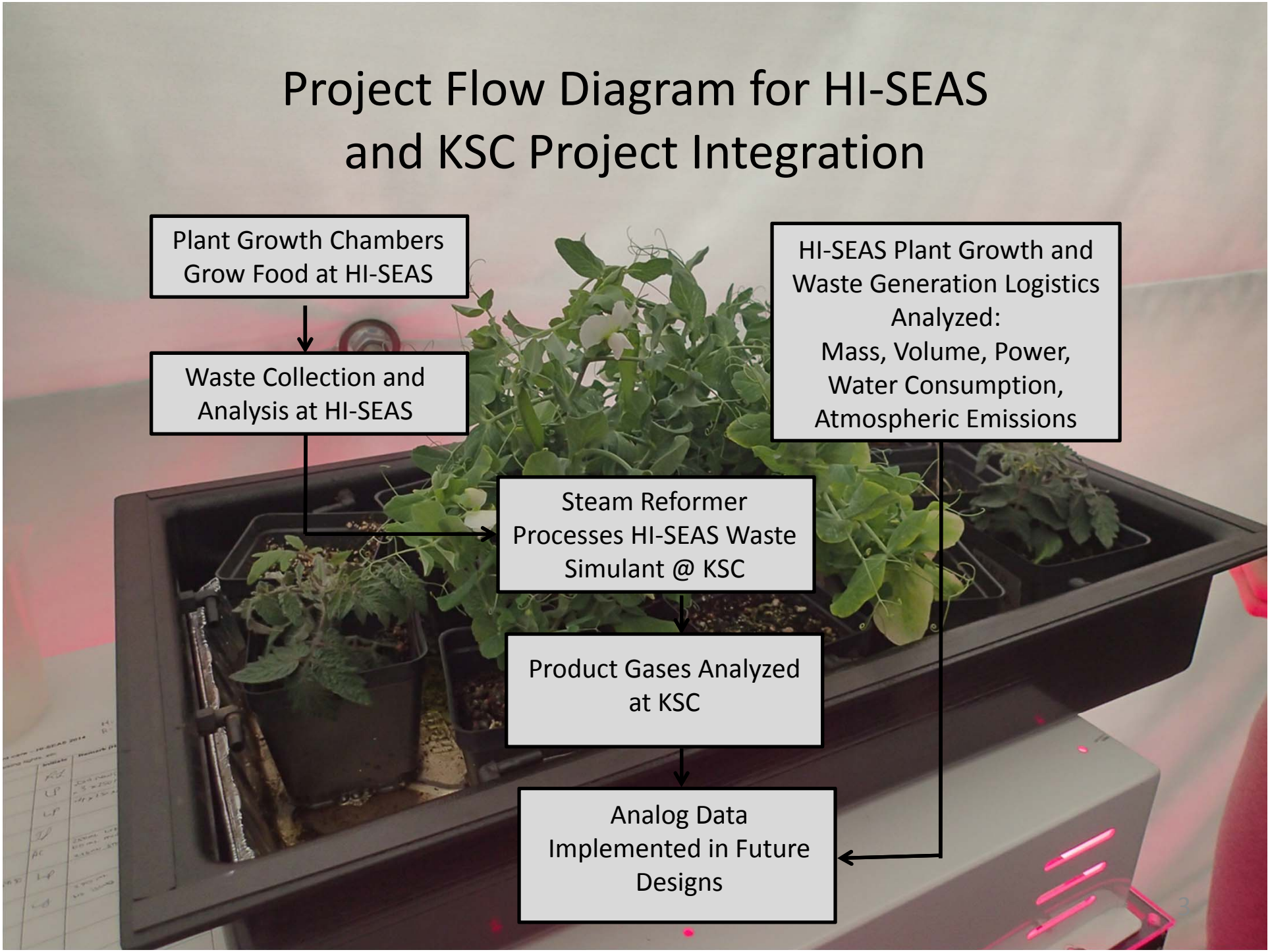
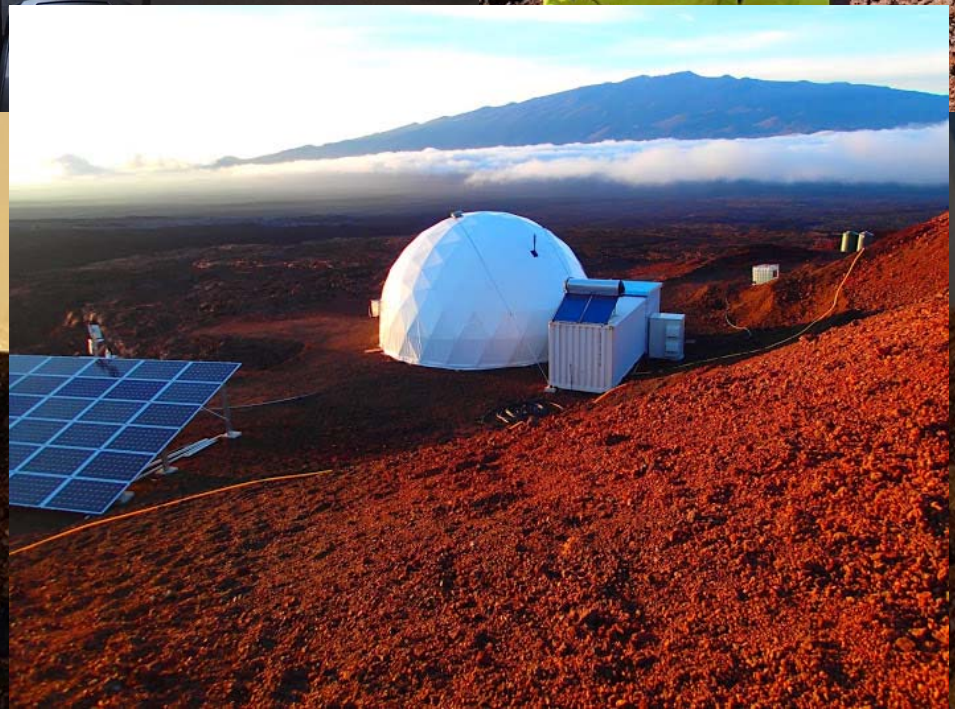
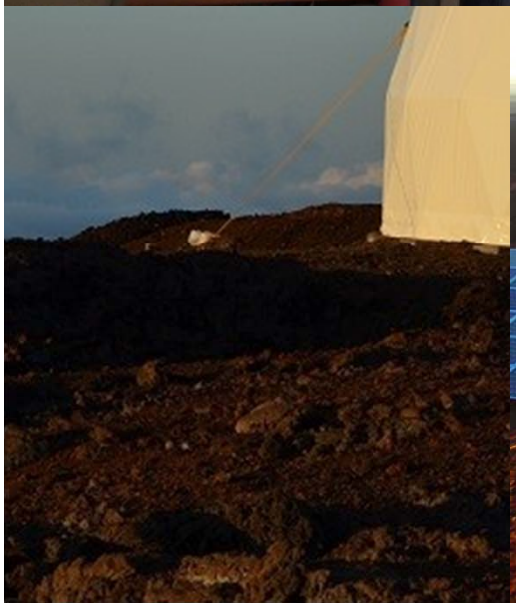
Motivation

- For long duration missions, self-sustainability and closed loop life support methods are required for living and working in deep space or on a planetary habitat.
  - This has significant technological challenges!
- Analog research can save money for space technology advancement by performing realistic operational tests on the ground
  - Raises technology readiness level!
- HI-SEAS Mission provided opportunity to investigate
  - Plant growth activity, logistical and plant waste management, power and water consumption effects of the plant and logistical waste, and potential waste conversion techniques using **KSC's TtG technology.**

Project Flow Diagram for HI-SEAS and KSC Project Integration

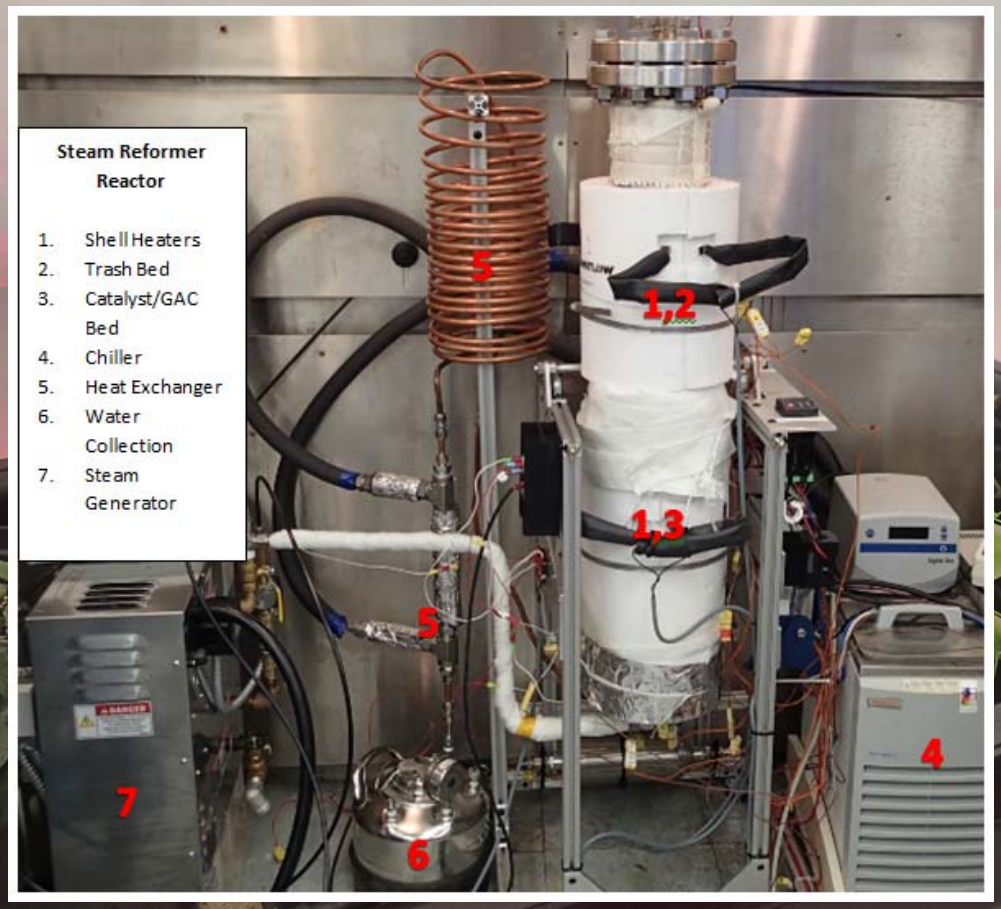







ORBITEC

Trash to Gas (TtG)

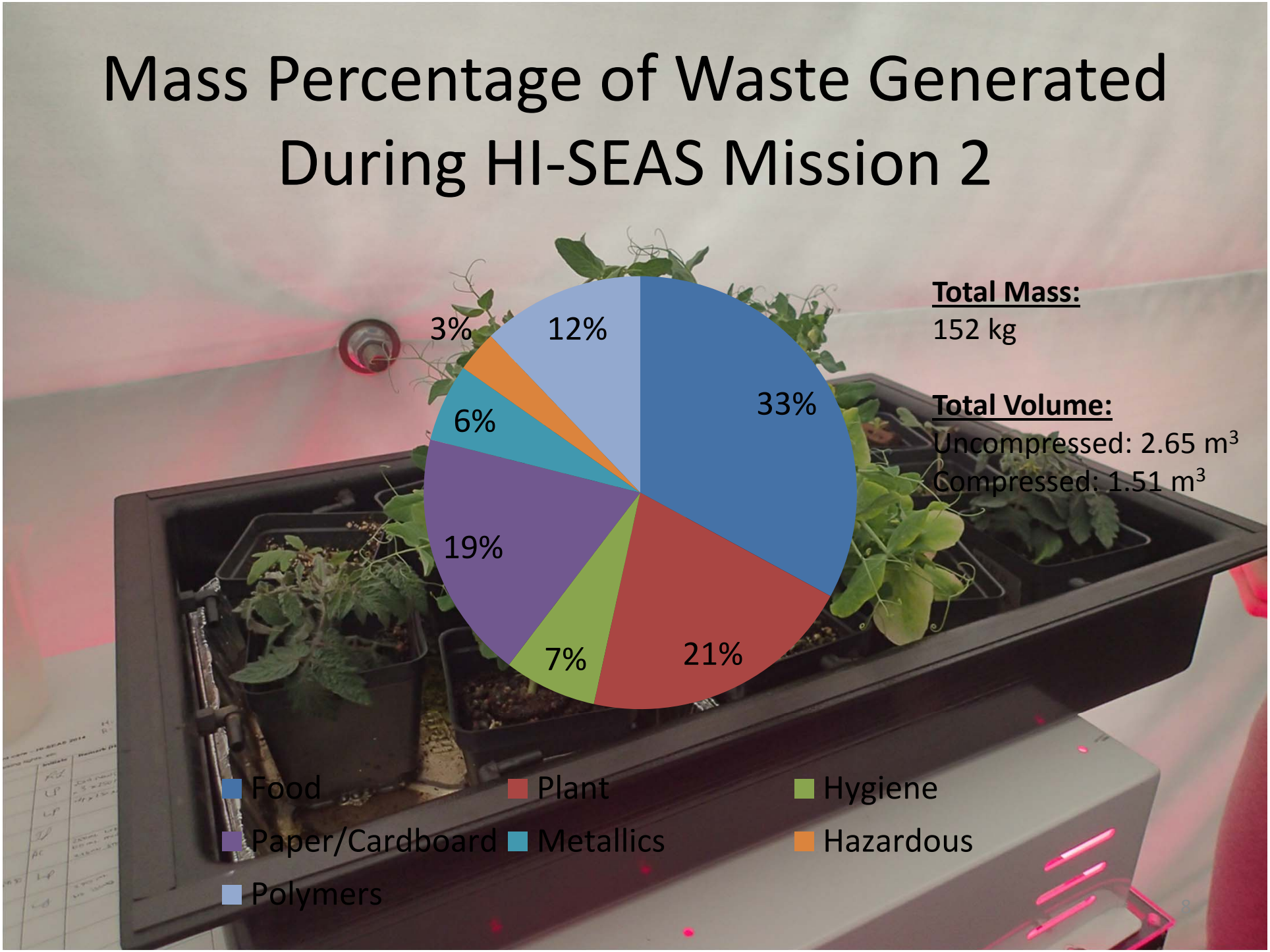


- Converts waste materials into useful products such as methane

$$Trash + O_2 + H_2O \rightarrow CO_2 + CO + H_2 + Ash + Tar$$

$$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$$

Mass Percentage of Waste Generated During HI-SEAS Mission 2



Total Mass:
152 kg

Total Volume:
Uncompressed: 2.65 m^3
Compressed: 1.51 m^3

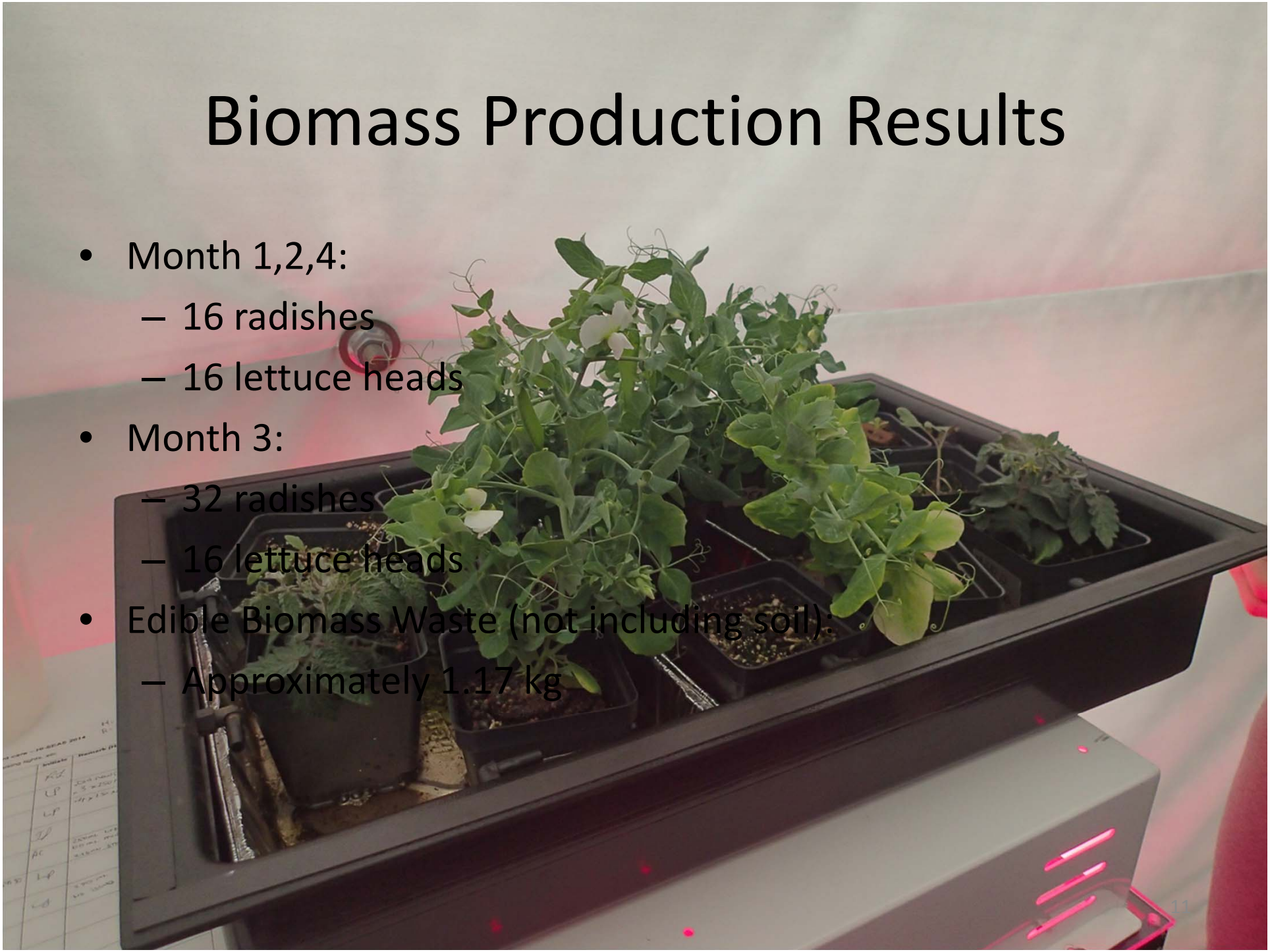
Water Consumption

	Month 1	Month 2	Month 3	Month 4
Total Water Use	1135.69	995.12	788.35	739.24
Plant Water Use	3.88	9.35	9.26	8.70

Power Use (kWh)

Month	Total Habitat kWh	Plant Light kWh	% Plant Light Use
1	1435	103.9	7.2
2	1482	103.5	7.0
3	1526	134.5	8.8
4	1333	134.5	10.1

Biomass Production Results



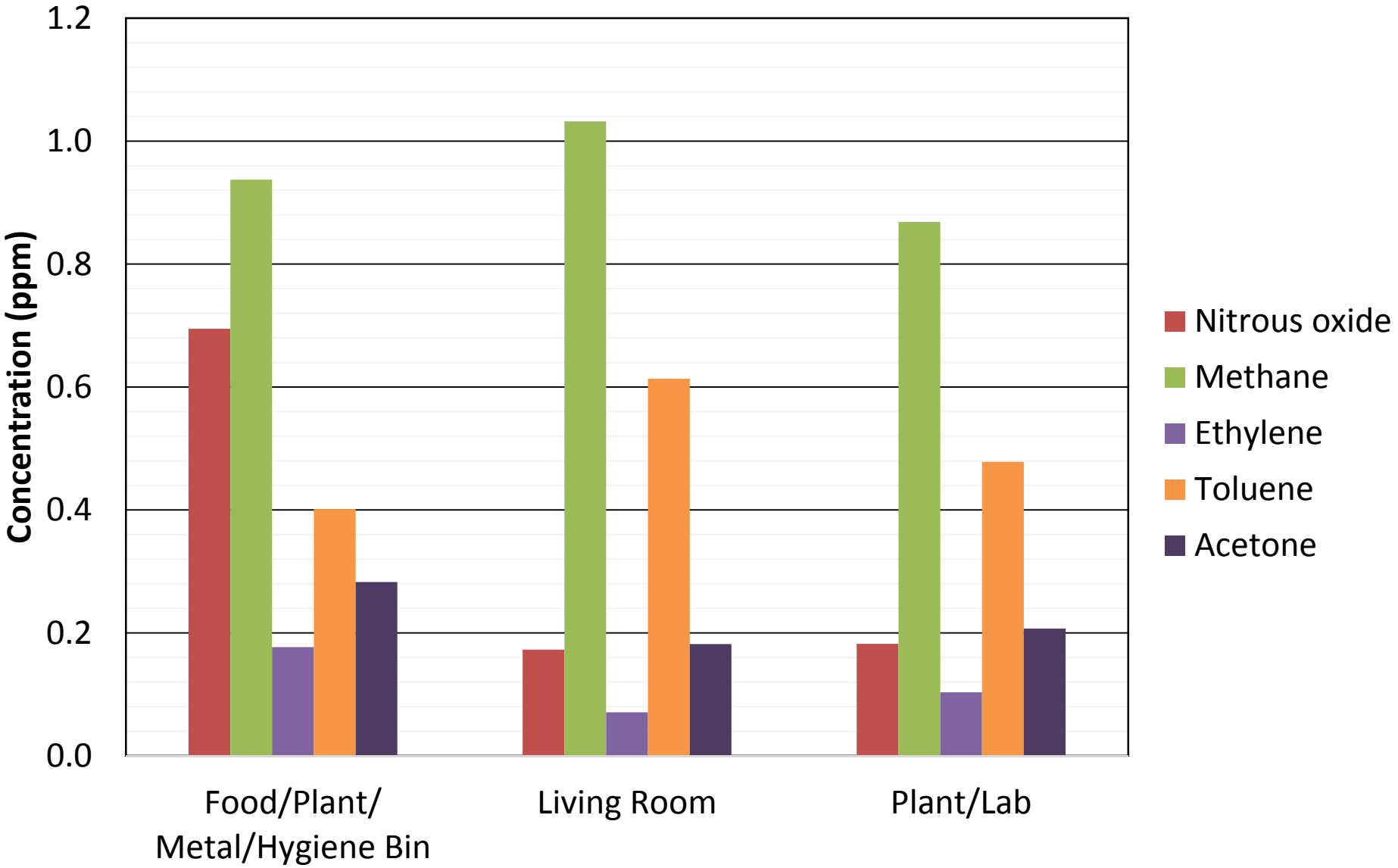
- Month 1,2,4:
  - 16 radishes
  - 16 lettuce heads
- Month 3:
  - 32 radishes
  - 16 lettuce heads
- Edible Biomass Waste (not including soil):
  - Approximately 1.17 kg

TtG Results

Different waste types processed by TtG steam reformer

- Successfully processed cardboard, plastic and food/plant waste mix
- Could produce 637 kWh from the waste generated during the mission, enough to power the plant lights

FTIR Results



CONCLUSION

- Addition of plants into this mission had little effect on utility use because not a main part of crew's diet.
- Having fresh food available for a crew has been shown on this mission via positive verbal crew feedback and survey data
- Plant waste was processed by the Trash to Gas process, demonstrating that it can be recycled.
- The amount of methane that could be produced from the waste is enough to provide energy to power the plant lights used in this mission
- The waste biomass and logistical waste becomes useful as it is incorporated into a closed loop cycle for support of human activity on a long duration missions.
- Much of this data and activity opens a portal for further advancement in creating a bio-regenerative closed loop life cycle system that supports human activity as well as recycles waste from missions.
- This work will be used for future designs into the TTG system so that even waste products from plants can be implemented to produce useful products.

ACKNOWLEDGEMENTS

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- Tracy Gill, NASA, KSC
- HI-SEAS P.I. Dr. Kim Binsted and Dr. Jean Hunter

Questions?

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Backup Slides

KSC Reactor Outputs

Waste Type	Water	Ash	Combustible
Cardboard	8.1%	7.3%	84.6%
Food/plant	66.7%	5.0%	28.3%
HFWS	40.3%	5.9%	53.8%

Water, Ash, and Combustible mass percentages of wastes.

Waste Type	CO_2, g/g	CO, g/g
Cardboard	2.2	0.5
Food/plant	1.0	0.1
HFWS	1.4	0.4

Carbon dioxide and carbon monoxide produced from each waste type, relative to the combustible mass