

Introduction



- **What is Circular Economy?**
- **Circular Economy in Space**
- **Life Support Systems in Space**
 - International Space Station
 - Moon and Mars
 - MELiSSA
- **Applications on Earth**

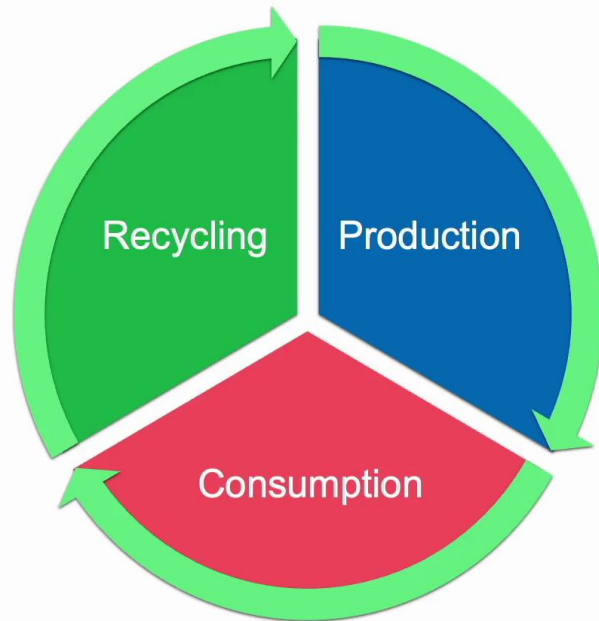
Hello, I am Tatiana Benavides, Manager of the Space Innovation Hub at ETH Zurich. In this lecture, we will cover the following aspects of space for circular economy. First of all, what is circular economy? Then, circular economy in space. Digging into the life support systems in space, particularly at the International Space Station and moving further away to the Moon, Mars. And as an example of an initiative by ESA, the European Space Agency, of a closed loop system called MELiSSA, standing for Micro-Ecological Life Support System Alternative. Before concluding, we will go through the terrestrial applications of such systems, and end with other examples of circular economy.

Notes

Summary



What is Circular Economy?



What is circular economy? A circular economy system is a cycle where the produced goods are consumed by the user and then come back to the production line as raw materials used in manufacturing. In contrast, linear economy does not recycle or reuse the materials after consumption, resulting in the generation of waste and pollution. It goes from a natural resource being manufactured into a product which is destined to become waste after consumption. By recovering the consumed product and turning it into the source that fits into the production line, circular economy takes into account the sustainability aspect and tackles global challenges like climate change, biodiversity loss, as well as reducing waste and pollution.

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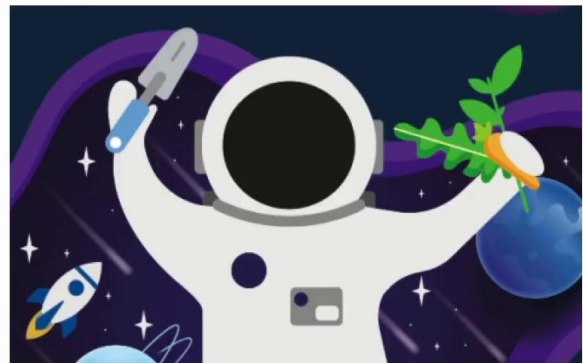
Summary



Circular Economy in Space



- Food and water production
- Waste management (treatment and recycling)
- Atmosphere monitoring and control (oxygen and carbon dioxide)



Circular Economy in Space. What do we need to survive in space? Think about the things that we have on Earth that we take for granted, such as the air we breathe, the oxygen, the food we eat, and of course, water. These are the basic needs that need to be fulfilled first when bringing astronauts to space to ensure their survival. And what happens with our waste after we eat or drink something? Urine, faeces, carbon dioxide, transpiration. On Earth, we have working pipe systems, at least in many places, but still critically missing in others. But in space, we have to provide a self-sufficient system to take care of the waste, what we call waste management. Taking proper care of waste and controlling the environment is crucial as dangerous amounts of carbon dioxide, untreated urine and faeces would be toxic and threaten the astronauts' lives. So what we need is food and water production, waste management for treatment and recycling of the waste, an atmosphere monitoring and control to provide oxygen and remove carbon dioxide.

Notes

Summary



1m 40s

Life Support Systems at the International Space Station



Image: ESA, NASA, Roscosmos / ESA – CC BY-SA 3.0 IGO



Image: NASA

Here we have a picture on the left of the International Space Station, called ISS for short. And on the right, you see a live support system example. It is interior view of the Leonardo Multipurpose Logistics Module carrying the two water recovery system racks for recycling urine into potable water, and a second toilet system, amongst other materials for the ISS.

Notes

Summary



2m 52s

Life Support Systems at the International Space Station



Image: ESA, NASA, Roscosmos

Image: NASA

The ISS recycles most of its air and water. Through water electrolysis, oxygen is produced from water using electricity. The oxygen is breathed by astronauts, which in turn produce carbon dioxide. And carbon dioxide, as it's toxic for humans in high levels, it has to be removed from the atmosphere through the environmental control system. The Advanced Closed Loop System, ACLS, from ESA recycles carbon dioxide on the space station into oxygen. Previously, oxygen on the space station was extracted only from the water that is supplied from Earth. But with the new system, half of the carbon dioxide is recycled, saving about 400 litres of water that needed to be launched to the station each year. Although water is recovered from urine and transpiration, it is still continuously resupplied, as the current deficiency of the systems at the ISS allow for only about 85 percent of the water to be recycled. In addition, food is also continuously resupplied from Earth to space and the waste is returned burning at the reentry back on Earth. Going deeper, even though urine is separated from the solid waste, only the water in the urine is recovered at the ISS and all the nutrients contained in the urine are wasted.

Notes

Summary



3m 15s



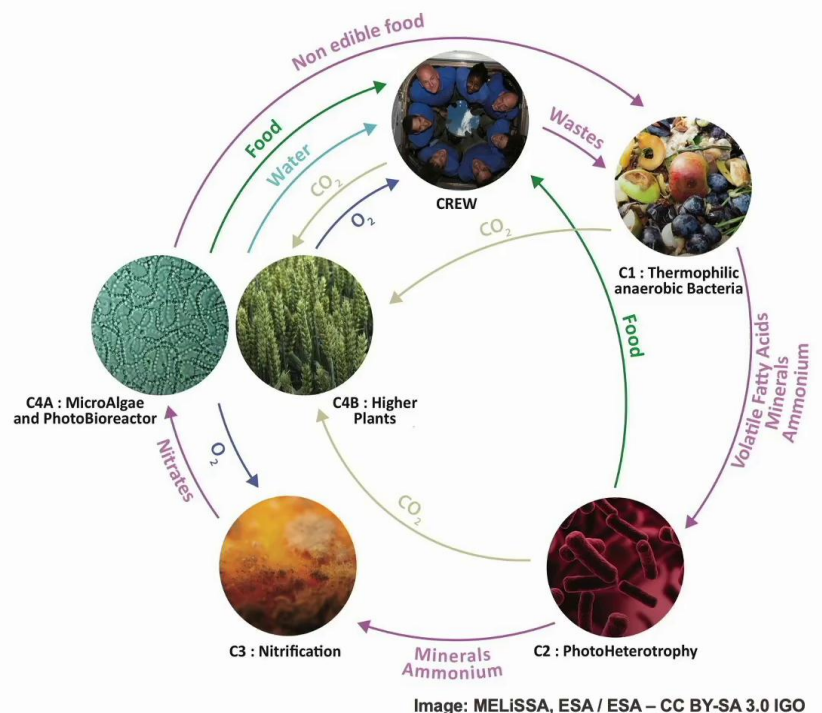
Urine is actually rich in nutrients like nitrogen and phosphorus needed for growing plants and algae. Thus, a complete urine recycling system will take advantage of these processed materials to fit into the circular economy loop. The further away from Earth and the longer the space missions, the more consumables that would be needed to keep the astronauts alive. Due to the cost, time, and distances in transportation, it is not feasible to resupply long-term space missions with resources from Earth. In the space exploration roadmaps, the next steps include the Lunar Gateway, a station that will be orbiting the moon in the next years. The long-term vision is to eventually colonise the Moon, having humans living and creating a civilization up there in preparation to then go further to take the first humans to Mars. With the current technologies, a three-year mission to Mars with six astronauts would require four rockets to take all the consumables needed for the astronauts to stay alive throughout the mission duration. This is too expensive and most likely not feasible. As we go farther away from Earth, we need to be independent and produce our own resources, taking care of the waste in a sustainable way. A closed-loop life support system would enable long-term space exploration. Let's see an example of this.

Notes

Summary



MELiSSA – Life Support System



An example of a life support system developed for space is the MELiSSA Initiative, standing for Micro-Ecological Life Support System Alternative. It started in 1989, inspired by the natural process occurring here on Earth in lakes, including the anaerobic fermentation, photoheterotrophy, nitrification, and photosynthesis. It is a collaborative programme between the European Space Agency, academia, and private partners. In the picture, the different cycles are illustrated. In reality, the different biological and chemical processes take place in photoreactors with compartments integrated for the different species like for bacteria, algae, and plants, closing the loop with the humans, here illustrated as the crew. As the human waste and carbon dioxide are turned into oxygen, food, and water, a complete circular economy system is created.

Notes

Summary





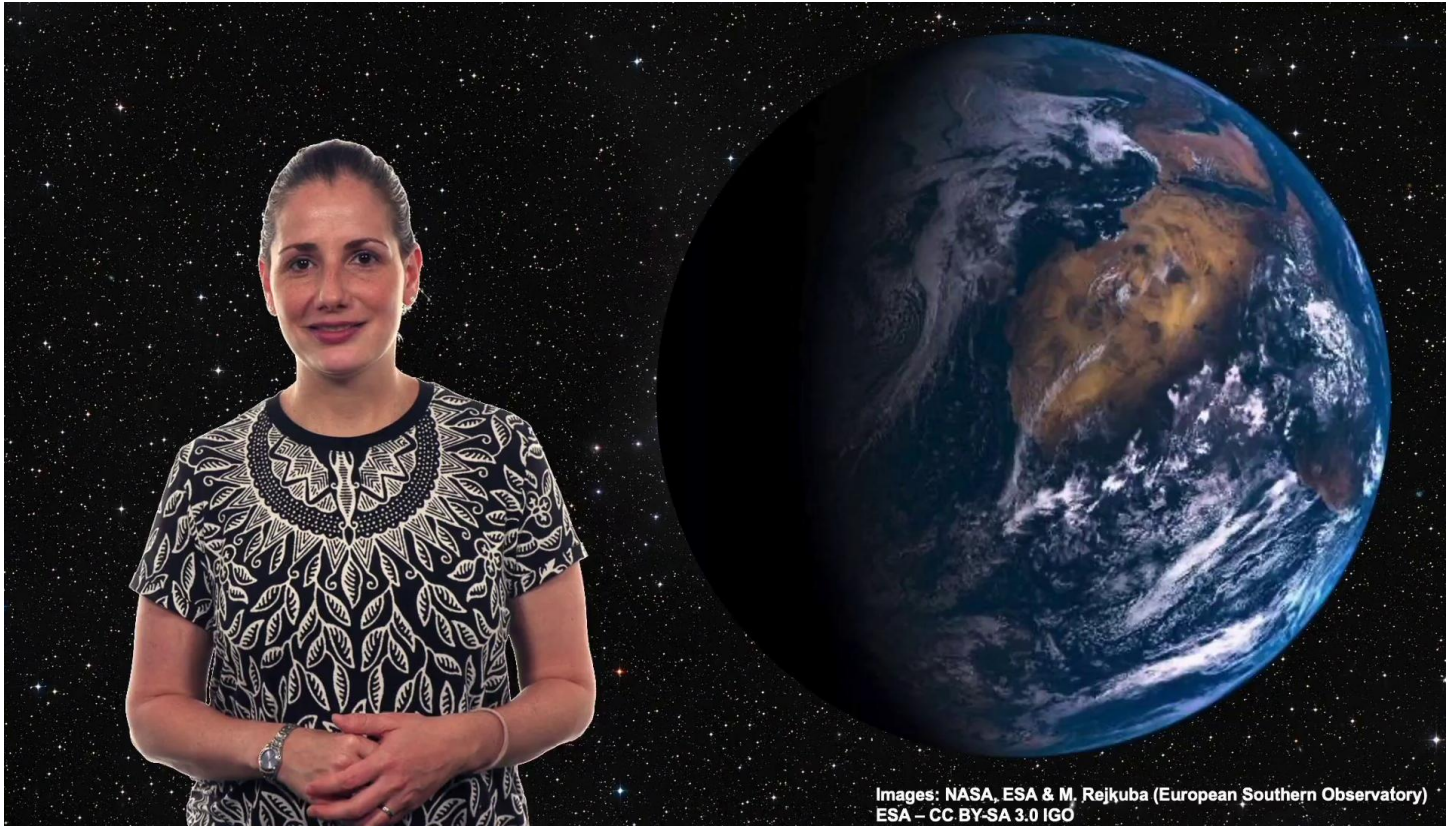
This is how the MELiSSA pilot plant with photoreactors looks like. It is an external ESA laboratory located in the Universitat Autònoma de Barcelona in Spain. The cycles that take place in the MELiSSA pilot plant compartments occur naturally in Earth as our planet acts as a whole, closed, regenerative life support system, producing water, oxygen, and food. In the biosphere, these complex processes include plants and algae doing photosynthesis, converting carbon dioxide into oxygen using light as an energy source. The water cycle processes called evaporation, condensation, precipitation, and filtration, recycle the water. And food production mostly through agriculture, uses fertilisers coming from animal waste. The life support systems are needed to enable life in space but are used on Earth to develop self-sustainable habitats and reduce environmental impact caused by human activities. Coming to the applications outside the space domain, the terrestrial applications. The life support systems enable decentralised services to support city infrastructure like housing and industry buildings as well as hotels, and mostly useful in places with water shortage and scarce food production, including remote regions not connected to the main city infrastructure.

Notes

Summary

7m 11s





Being inspired by the limited resources available in space create sustainable solutions for Earth, particularly for extreme and isolated areas in Earth like the mountains, deserts, isolated charters, and the Antarctica. As an example, in the French-Italian Antarctica base called Concordia Station, all the water used for hygiene purposes is recycled. Imagine how clean our cities would be if we all live under this principle. A profitable business model for life support systems in a circular economy fashion would have a market here on Earth targeting clean cities, avoiding food waste, saving resources like water, and reducing energy costs. Other applications for these systems include the microbial factories as algae can be used to produce biofuel, bioplastics, bioconcrete, carbon fibre, proteins for food supplements, as well as pigments and polymers for manufacturing materials.

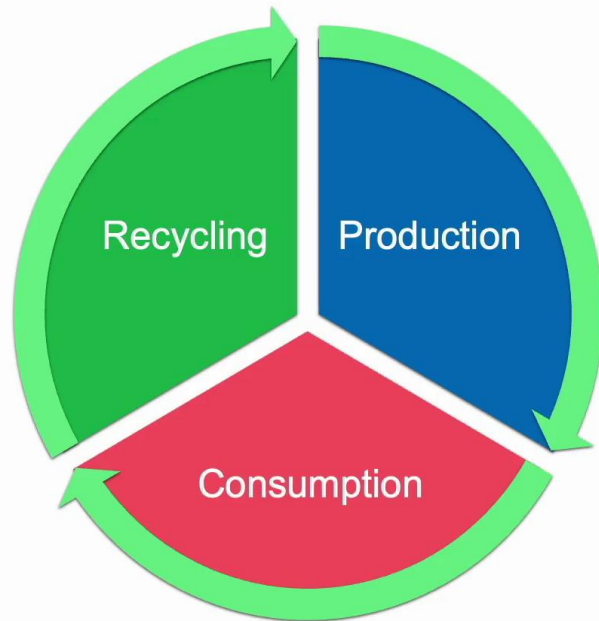
Notes

Summary



8m 40s

Conclusion



As a conclusion, life support systems are a perfect example for a circular economy with a sustainable impact, turning waste into food and every generation all in a cycle. Other examples that fit into the circular economy loop are the recycling of materials such as plastic, or tires and rubber waste to produce roads and bricks for constructions, So the use of carbon extracted from trash to produce fuel for transportation, and creating another purpose and reuse either electrical devices themselves or their components, as well as any other businesses that use recycled content and recycled materials in their products. With this, we close the Space for Economy lecture. I hope you enjoyed it and got some insights on how technologies needed for space can be used to improve the life here on Earth in a sustainable manner.

Notes

Summary



9m 44s