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Pyrolysis of plastic waste: opportunities and challenges

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https://news.cision.com/vtt-info/r/vtt-to-add-new-methods-to-the-plastics-recycling-chain,c2837513

Pyrolysis of Plastic Waste: Opportunities and Challenges

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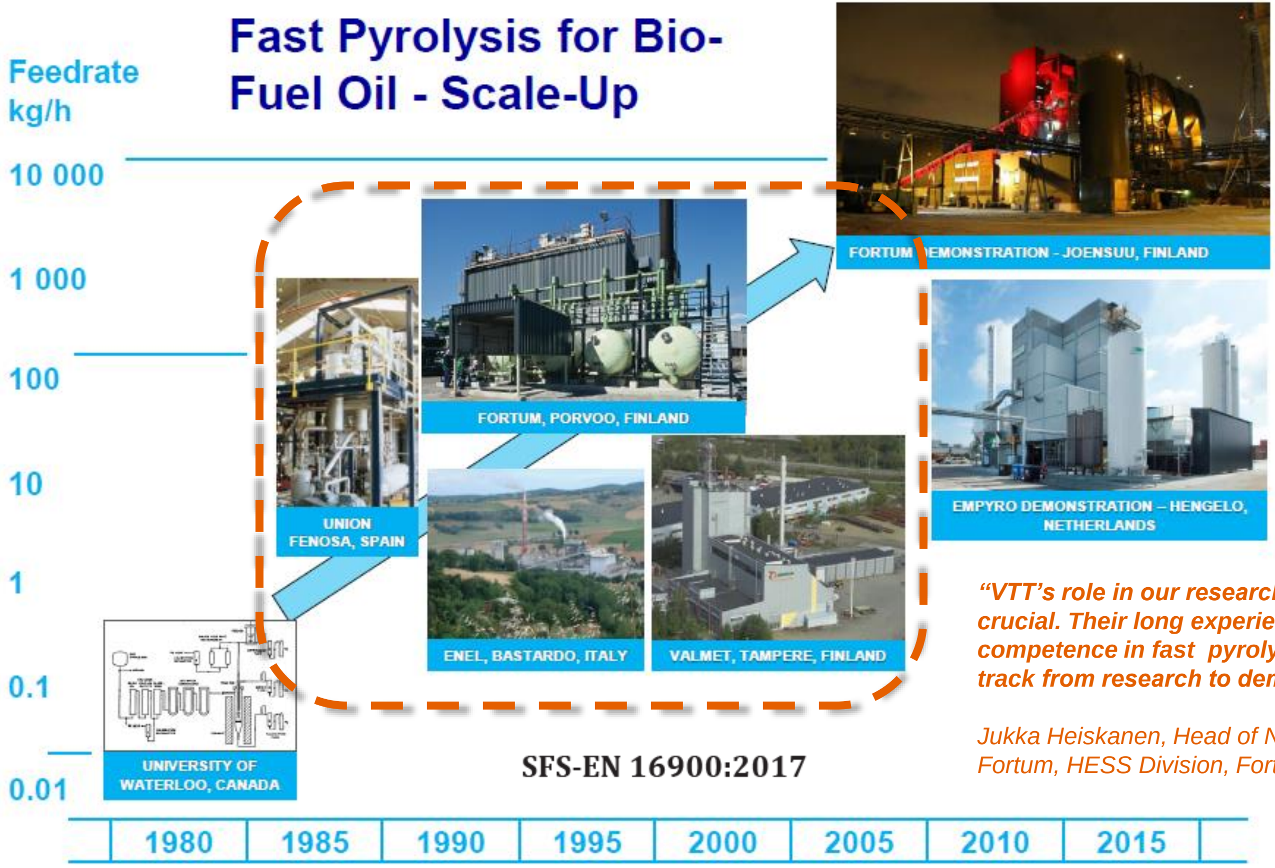
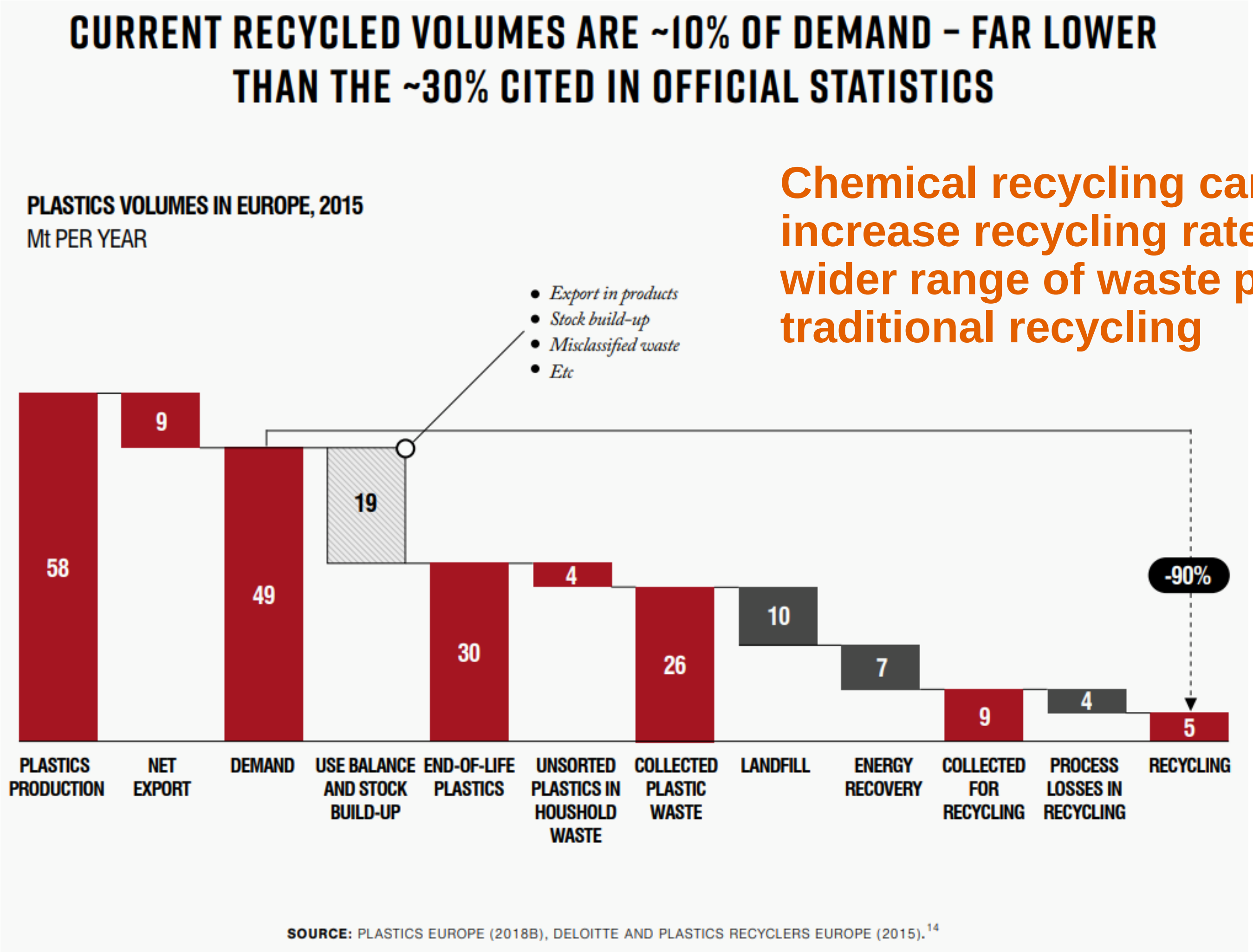


TRL 8 for wood
50 000 t bio-oil/a

"VTT's role in our research consortium has been crucial. Their long experience and world class competence in fast pyrolysis has enabled a fast track from research to demonstration."

Jukka Heiskanen, Head of New Energy Concepts
Fortum, HESS Division, Fortum Power and Heat Oy

- **VTT participated in all European pilots and was part of the industrial consortium to demonstrate fast pyrolysis technology**



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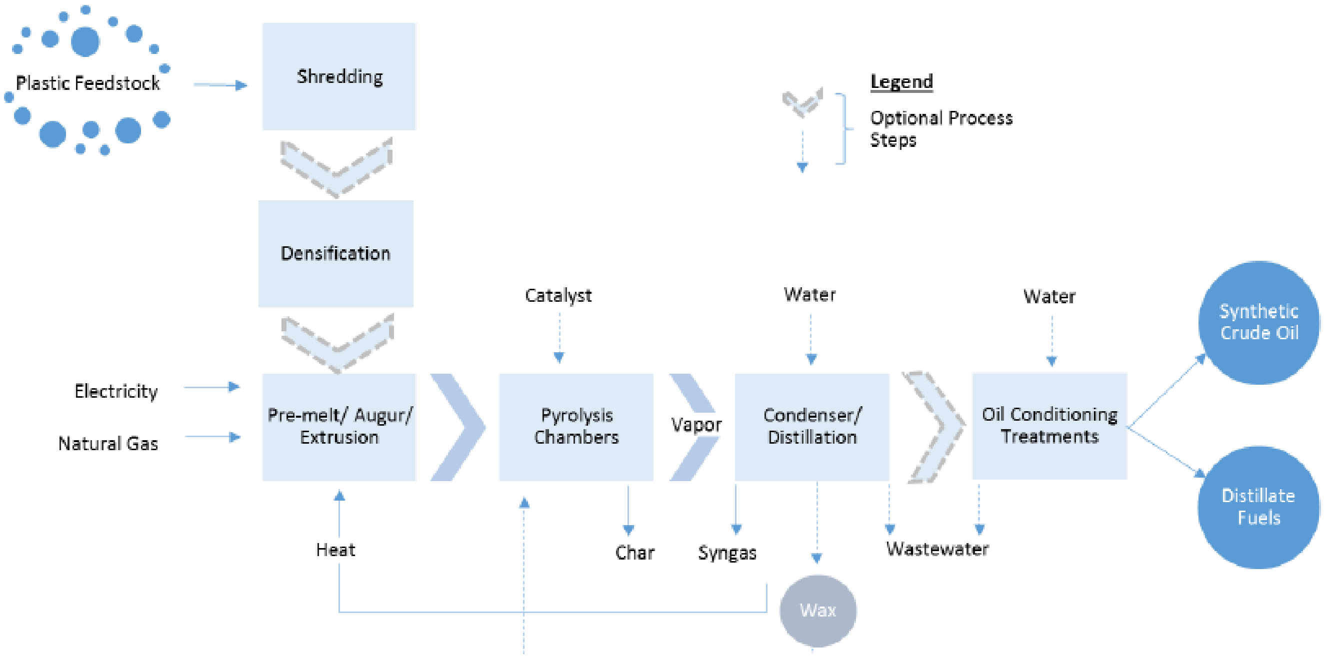
Chemical recycling can significantly increase recycling rate as it can utilize wider range of waste plastics than traditional recycling

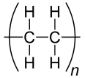
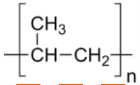
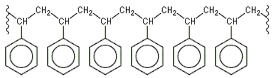
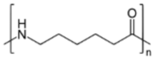
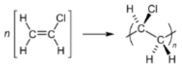
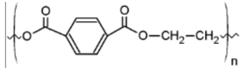
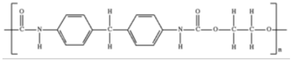
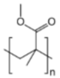
Ref. Material Economics, 2018. The circular economy – a powerful force for climate mitigation. Editors: Enkvist, P-A. & Klevnäs, P. 2018 https://media.sitra.fi/2018/06/12132041/the-circular-economy-a-powerful-force-for-climate-mitigation.pdf

Pyrolysis of plastics is thermal or catalytic decomposition of a material in an oxygen-free environment into liquid product for chemicals or fuels



OCEAN RECOVERY ALLIANCE 2015

Valuable substances from pyrolysis

RESIN	STRUCTURE	MAJOR ORIGIN OF WASTE	THERMOLYSIS PRODUCT
PE		Household, industrial plastic packaging, agricultural plastics	Waxes, paraffins, olefins
PP		Household and industrial plastic packaging, automotive	Waxes, paraffins, olefins
PS		Household, industrial plastic packaging, construction, demolition, WEEE	Styrene, its oligomers
PA-6		Automotive waste	Caprolactam
PMMA		Automotive, construction waste	MMA (methyl methacrylate)
PET		Household plastic packaging	Benzoic acid, vinyl terephthalate
PUR		Construction, demolition, automotive	Benzene, methane, ethylene, NH3, HCN
PVC		Construction plastic waste	HCl (< 300C), benzene

OIL REFINERY FEEDS > CHEMICALS, DIESEL

MONOMERS

UPGRADING > CHEMICALS, FUELS

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Commercial scale (up to 60 TPD) plastic pyrolysis systems in USA, Europe, and Asia

- **RES polyflow (USA), 60 TPD**, light liquid
- **VadXX (USA), 60TPD**, On Spec Middle Distillate #2 Diesel to Blending
- **Nexus (USA), 50 TPD**, Thermal decomposition in a melting vessel, Blend of light crude, diesel, gasoline, kerosene blendstock, wax
- **AGILYX (USA), 10-50 TPD**, Continuous thermal, dual screw reactor, Light synthetic crude oil to Refinery
- **Recycling Technologies (UK), 20 TPD,** low sulphur hydrocarbon Plaxx™
- **Thermal cracking - BP process (Hamburg, Germany), 1 TPD**, low temp fluidized bed process, Dechlorination, Light and heavy wax

Plastic Energy SI System (Cynar) in Almeria, Spain

- **Plastic Energy, THERMOFUEL (Japan, Ireland, UK, Spain), 20 TPD,** Thermal degradation in STR

Bottlenecks in WEEE, ELV and plastics packaging value chains

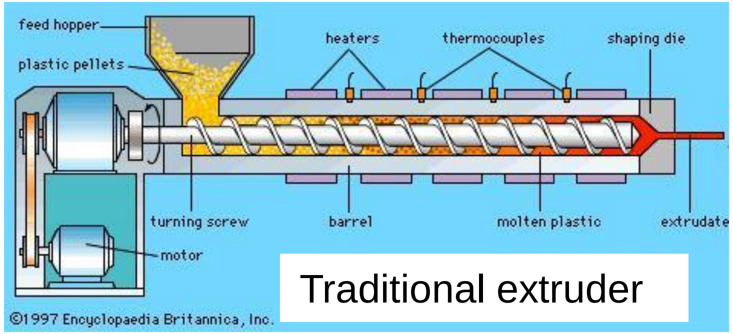
- Main bottlenecks:
  1. Inadequate collection and monitoring (including export),
  2. Composition of the input material (including product design),
  3. Recycling technologies,
  4. Economic incentives, and
  5. Legislative barriers.
- The bottlenecks were interrelated and linked to the following three categories:
  - **Inefficient collection and monitoring**
  - **Sorting, recycling and recovery technologies**
  - **Composition of the input material/product design**
- Uniform solutions would be applicable to several waste or recycling streams, i.e. technical solutions for recycling of plastics and minor metals, **implementation of best collection practices, better information about the material flows and transparent statistics as well as regulation and guidelines enabling introduction of technical or systemic solutions.**

Key challenges and possible solutions for thermolysis of plastics*

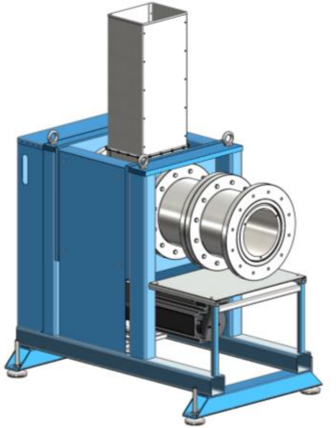
Key challenge	Possible solutions
Discontinuous availability of waste due to lack of long-term binding agreements with feedstock suppliers	**Waste supplier in the pyrolysis consortium**
Complex sorting and conversion technologies	**Cost-effective pretreatment/conversion techniques for heterogenous waste** ➢ Modular extruder to process heterogenous industrial plastic waste into homogenous melt/granules (VTT patent pending) ➢ Novel integration of pretreatment and conversion (VTT patent pending)
Permitting, legislative requirements Unclear legislation related to products (i.e. fuels) from chemical recycling	**Waste hierarchy** has been updated by addition of life cycle thinking into waste policy. Waste hierarchy can be overtaken if it is justified by **LCA**. **Lobbying and clear dissemination** **End-of-waste status, REACH**

* Results of a national WasteBusters project 2017-18 (https://news.cision.com/vtt-info/r/vtt-to-add-new-methods-to-the-plastics-recycling-chain,c2837513)

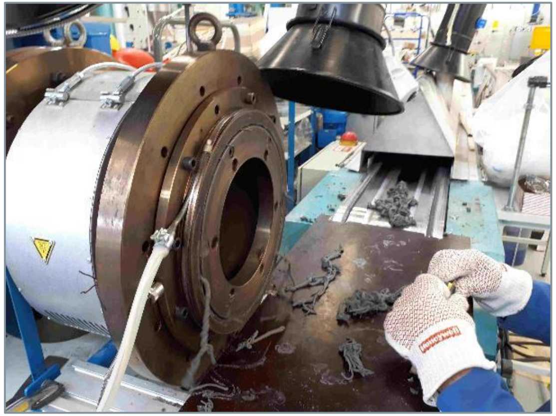
Integrated material pretreatment to pyrolysis



Traditional extruder


Novel extruder

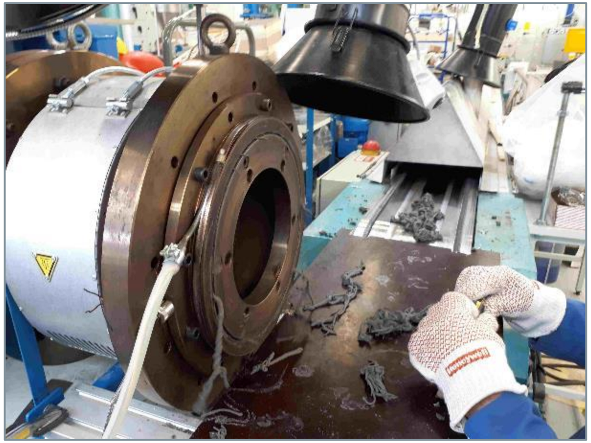
- Scalable compact modular extruder (patent pending)
- Heterogenous feed including foils which otherwise are difficult to process
- Output i.e. granules or melt to be fed directly into the pyrolyzer
- Possibility to remove chlorine



WO18037164 A1 Single screw extruder with hollow rotor member

Modular extruder decreases the process steps in feedstock recycling

- Various industrial waste including fluffy plastic films, plastic bottles, canisters and mixed plastic waste including paper, cartoon and pieces of wood were treated.



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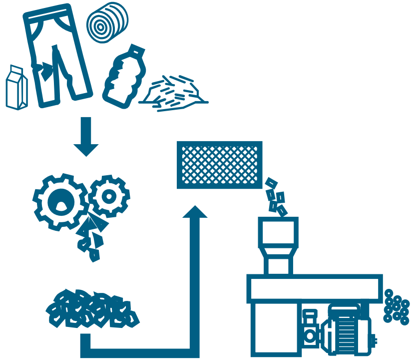
Integrated pyrolysis approach



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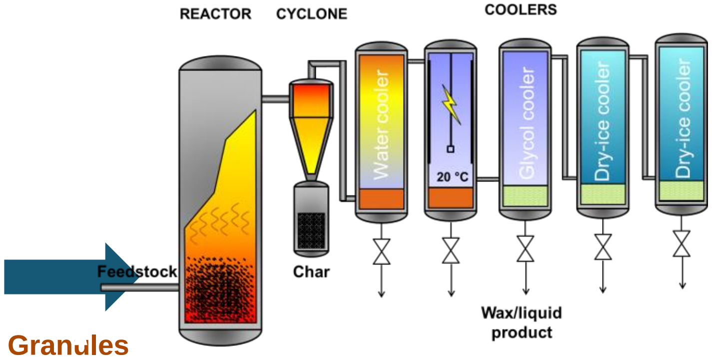
Granules or melt



BFB technology

Liquid oil

Wax

Waste › **Pretreatment** › **Pyrolysis** › Upgrading › Products

Reactor comparison for plastic thermolysis

Green = good, **Orange** = satisfactory, **Red** = Poor

	Temp. control	Heat transfer	Particle size flexibility	Residence time flexibility	Process flexibility	Thermal mode operation	Catalytic mode operation	Value of obtained products	Scale-up flexibility	Economic feasibility
Fixed Bed	Red	Red	Orange	Green	Red	Orange	Orange	Green	Red	Orange
BFB	Orange	Green	Orange	Orange	Green	Green	Green	Green	Orange	Orange
CFB	Orange	Green	Orange	Orange	Green	Green	Orange	Green	Orange	Red
Rotary kiln	Red	Red	Green	Green	Orange	Green		Orange	Orange	Orange
Melting vessel	Red	Red	Orange	Green	Orange	Green		Orange		Orange
Extruder	Orange	Red	Orange		Green		Orange	Green	Green	Orange

U. Arena, M.L. Mastellone, Fluidized Bed Pyrolysis of Plastic Wastes, in: Feedstock Recycling and Pyrolysis of Waste Plastics, John Wiley & Sons, Ltd, 2006; 2006, pp. 435-474.

Permitting, legislative requirements

- **Under ISO15270 pyrolysis is recognized as forms of feedstock recycling technologies when the products are used for the production of fuels or raw materials**, rather than for combustion and energy recovery which would be considered a waste-to-energy process
- Waste hierarchy has been updated by addition of life cycle thinking into waste policy. **Waste hierarchy can be overtaken if it is justified by LCA.**
- **Liquid end-product from pyrolysis to be classified as product and compared with the product it will replace, end of waste status and REACH**
  - In order to get ‘End of waste’ status following criterias have to be fullfill:
    - The product is commonly used for specific purposes;
    - There is an existing market or demand for the substance or object;
    - The use is lawful i.e. the product fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products; and
    - The use will not lead to overall adverse environmental or human health impacts.

Carbon footprint of pyrolysis of plastic waste

- **The carbon footprint of the pyrolysis of plastic waste was 15-60% lower compared to the business as usual scenarios.** (Finnish case study)
- **Pyrolysis has the potential to reduce climate impacts**
- **Important aspects in LCA assessment GHG emission savings, possibilities for integration, potential for compensating primary resource use with recycled raw materials, possibilities for upcycling due to removal of harmful substances**
- **Sustainability is context specific, and results are always sensitive to applied assumptions and data.**
- **A study regarding potential allocation factors for plastic waste has begun in the context of the EU-funded NonTox project (2019-23)**

➢ ***Using waste plastic as raw material reduces the carbon footprint of end products and decreases dependency on crude oil***

Integration of mechanical and chemical recycling

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- **Optimising collection and sorting**
  - Improve the efficiency of collection, monitoring, sorting

- **Life cycle assessment**
- **End-of waste status, REACH**
- **Product specifications, standards**

Waste → **Pretreatment** → **Pyrolysis** → **Upgrading** → **Products**

- **Optimising mechanical recycling**
  - Plastic waste not suitable for mechanical recycling to be processed by pyrolysis

- **Optimising conversion and post-treatment**
  - Improve conversion technologies - effect of reactor type, scaling, thermal behaviour of additives
  - Product design

➢ ***Optimisation of the whole value chain from waste to specified product***

Thank you!

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