Economic and Sustainability Evaluations of Carbon Dioxide Capture and Transformation Technologies

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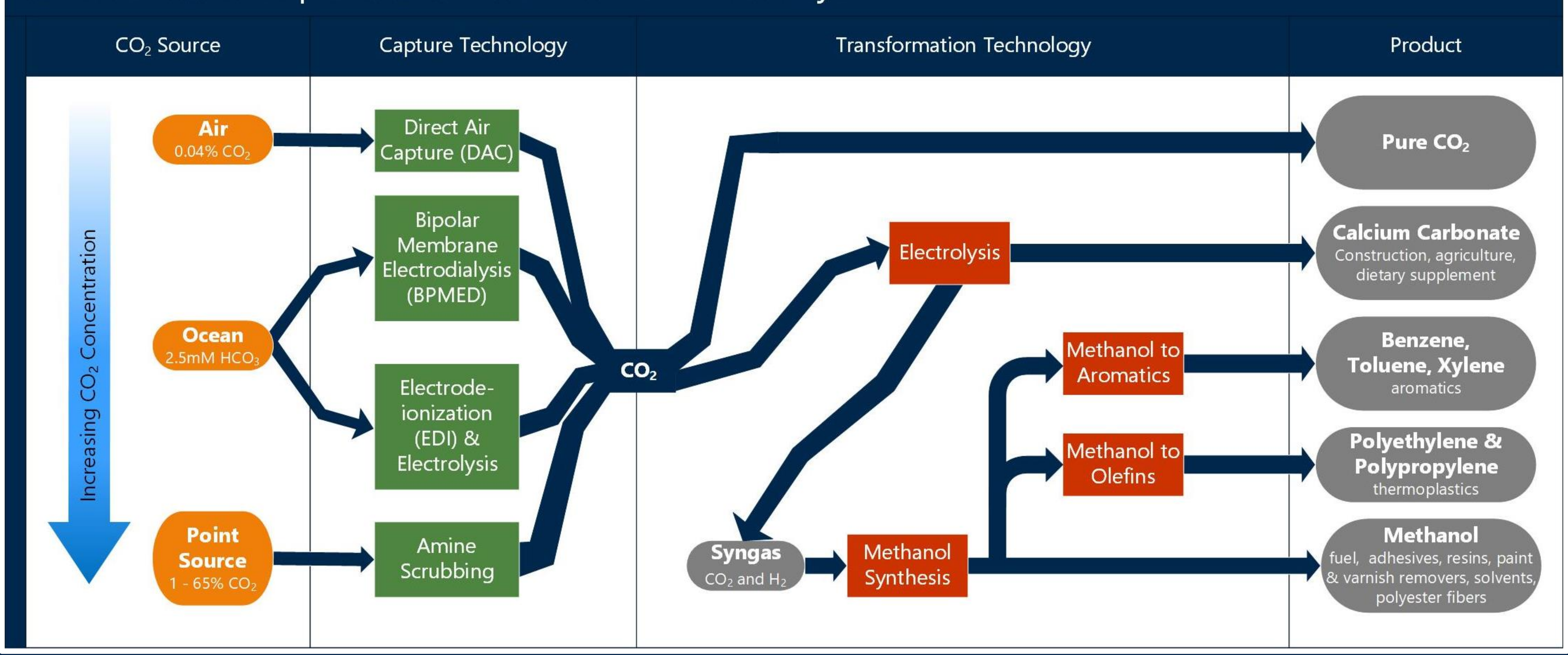
Summary

- Environmental benefit to capturing CO2 from the environment
- Economic benefit in transforming CO2 into value-added products
- Current challenge is to utilize these technologies in an economically viable way
- Cost- and energy- based comparison of existing CO2 capture and transformation technologies
- Scientific literature analyzed using thermodynamic and data-driven analysis
- Identify most economically feasible and least energy intensive combinations of capture/transformation technology
- Provide guidance to direct ongoing research in the carbon capture field

Carbon Dioxide Capture and Transformation Pathways



Energy Considerations

Energy requirements are evaluated for each process individually, as well as for complete sequences of processes. [1]

For capture processes, energy requirements are compared against the thermodynamic minimum energy to separate CO2 from the source and pressurize it. [3]

Efficiency from electrical to thermal energy is assumed to be 100%

$$W_{min,s} = \frac{-R_u T_o \sum_i y_i \ln(y_i)}{M_m}$$

$$W_{min,p} = nR_u T_o \ln\left[\frac{P_o}{P_f}\right]$$

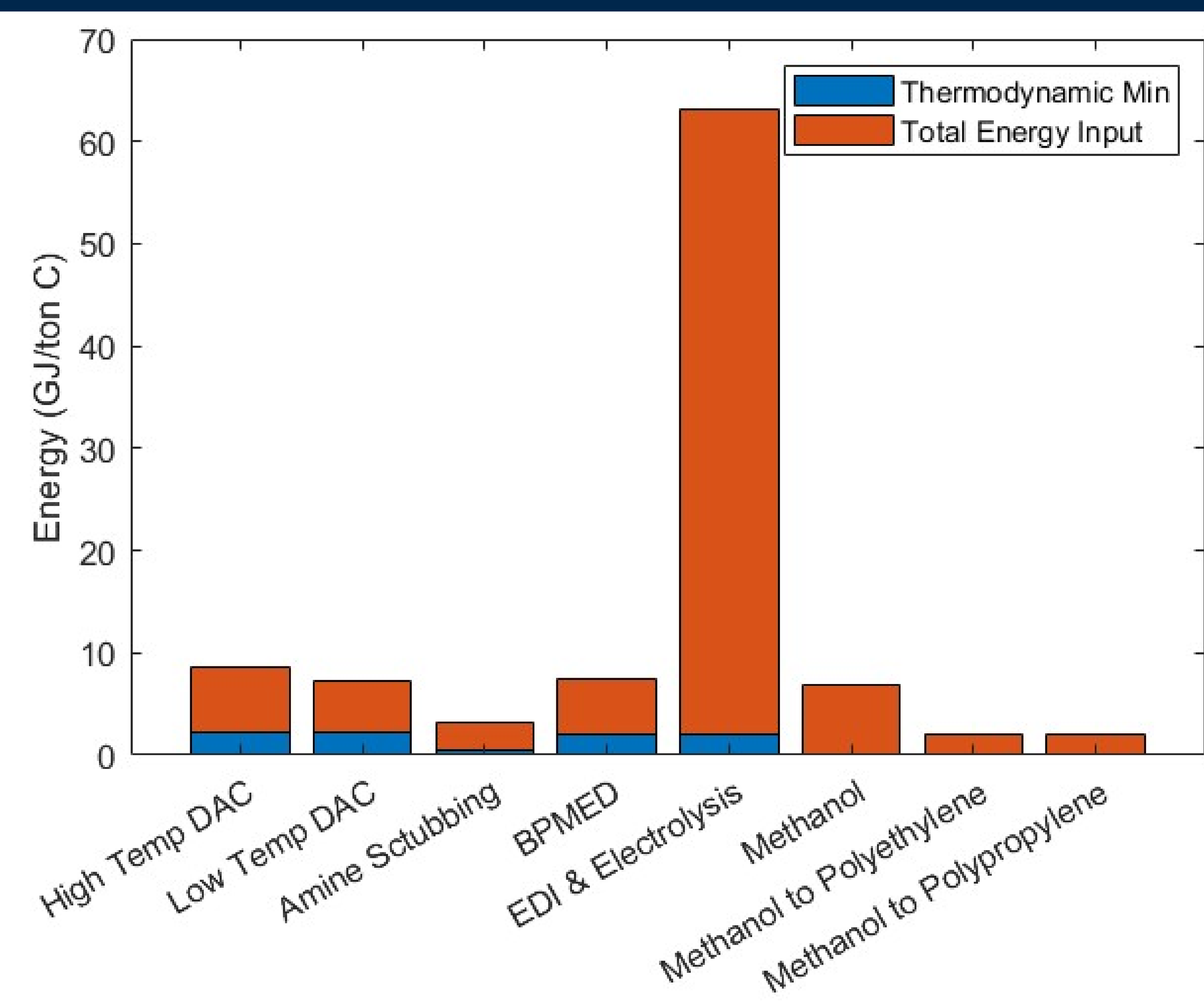


Figure 1. Energy required for each individual technology, both capture and transformation (GJ/ton C). Thermodynamic minimum energy requirements are shown for capture technologies only.

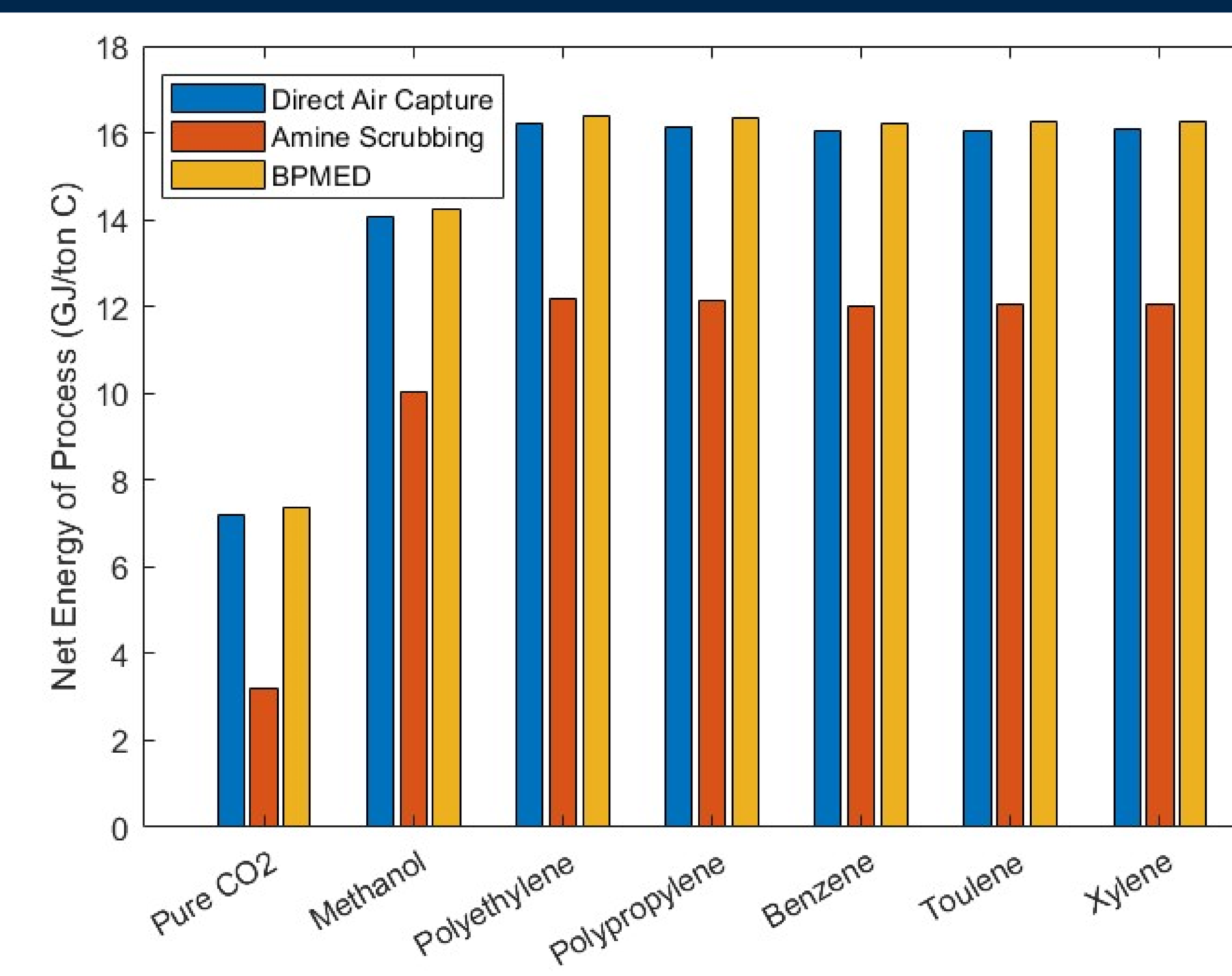


Figure 2. Net energy of complete processes for each product, including capture and transformation (GJ/ton C). For pure CO2, this is the energy input of capture. For fuels, the energy contained in the products (HHV) is subtracted. For non-fuels, the energy from alternative production methods is subtracted.

Cost Considerations

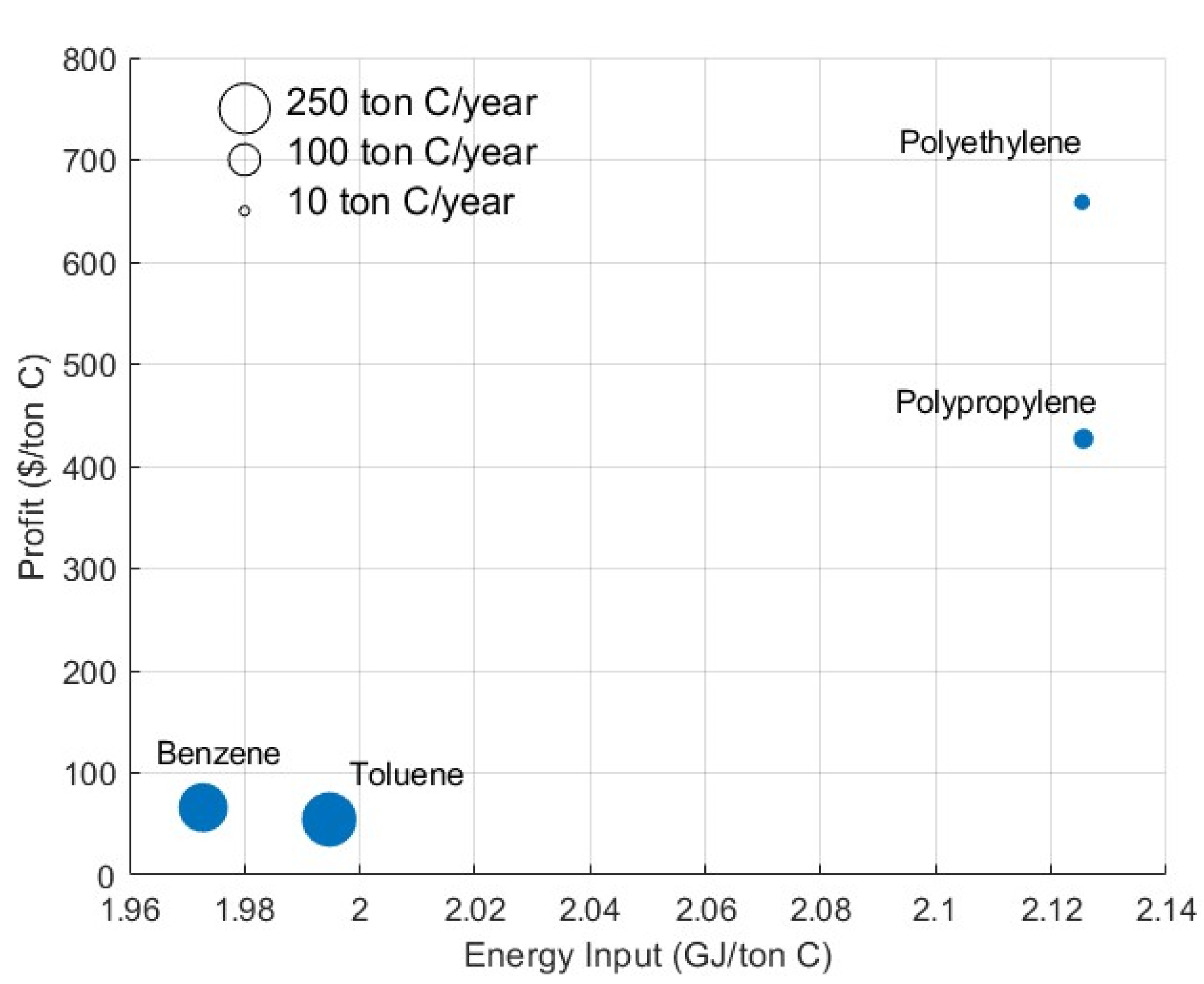


Figure 3. A comparison of estimated profits associated with each production $/ton C.[1] [2] Process energy requirements are shown on the x axis in GJ/ton C. All values correspond to processes which use Amine Scrubbing for capture. Size of each circle corresponds to the current United States market size for the product in ton C/year. [2]

Conclusions

Among capture technologies, Amine Scrubbing is currently the least expensive and least energy intensive, due to the greater concentration of CO2 in point sources than in the atmosphere.

For entire processes:

- Maximum profit value is **4,184 $/ton C** captured
- Minimum energy demand is **1.98 GJ/ton C** captured

Emerging CO2 capture and transformation technologies should aim to improve one or both figures.

Further Research Areas:

- Additional products and capture/transformation technologies
- Ideal processes for specific industries
  - What industries are creating CO2 through point source emissions?
  - Of those, which require large amounts of value-added products?
- Consideration of additional environmental impacts (eutrophication, GWI, water use, etc.)

References

[1] Rosental, Marian, et al. "Life Cycle Assessment of Carbon Capture and Utilization for the Production of Large Volume Organic Chemicals." Frontiers, Frontiers, 1 Jan. 1AD, https://www.frontiersin.org/articles/10.3389/fclim.2020.586199/full. [2] Hall, L. (2019). Toluene. ICIS Chemical Business, 296(2), 38. Retrieved from https://proxy.lib.umich.edu/login?url=https://www.proquest.com/tradejournals/toluene/docview/2268283965/se-2?accountid=14667 [3] Chicago. Çengel, Yunus A. Thermodynamics : an Engineering Approach. Boston :McGraw-Hill Higher Education, 2008.

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