Team INAM
Substrate Feed Control Algorithm

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MIT ENERGY HACKATHON 2017

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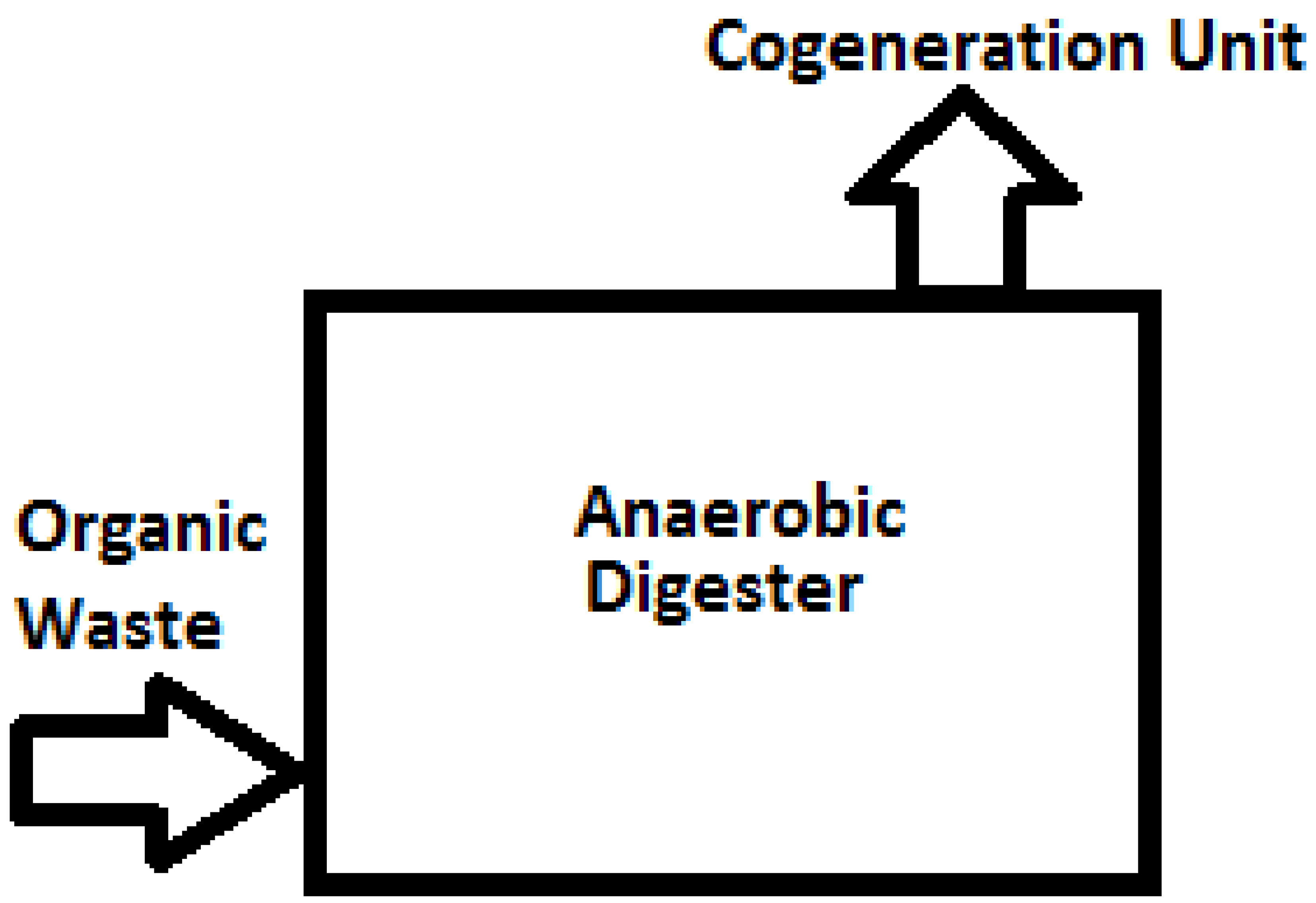
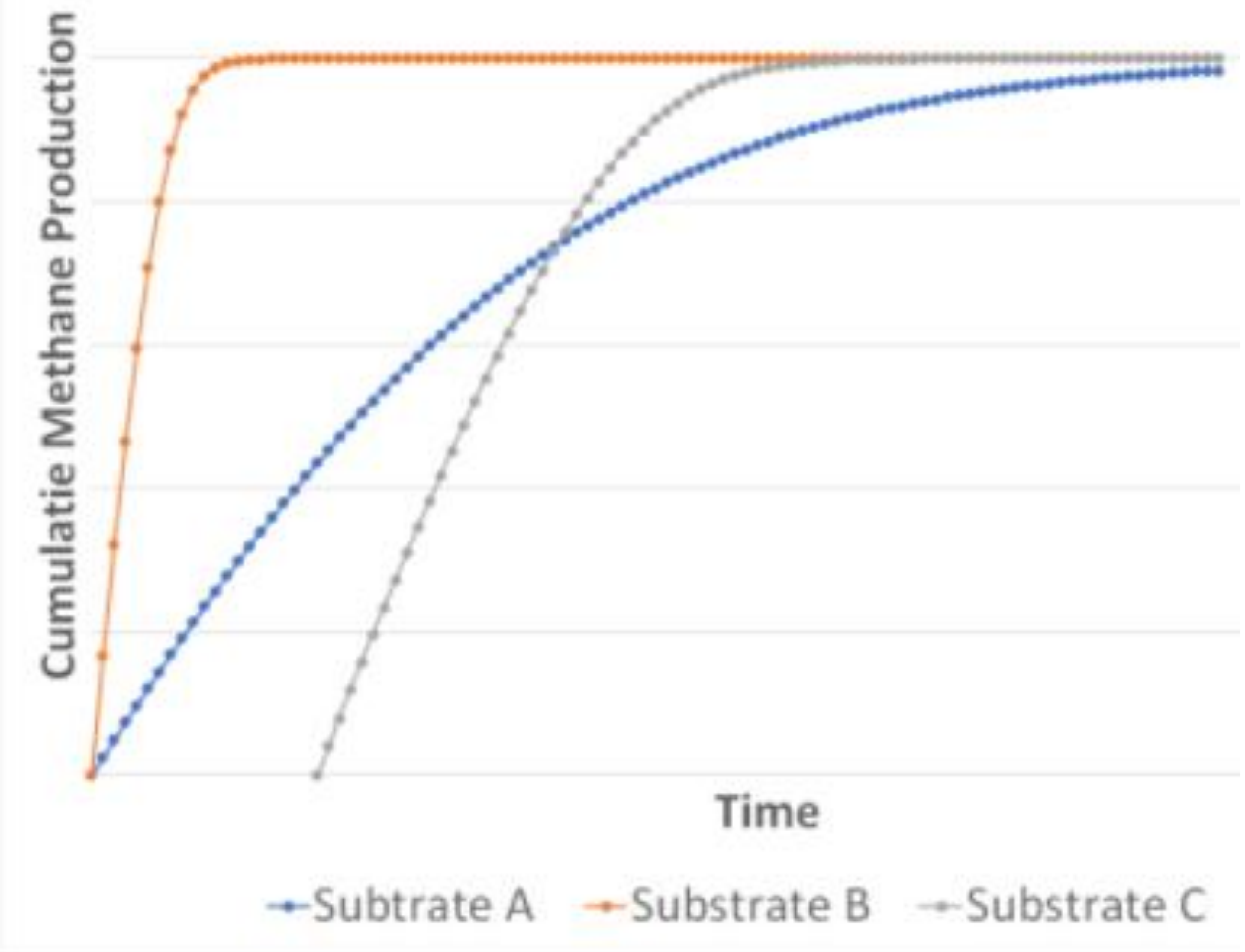
Anaerobic Digestion Introduction

- Biogas is produced in an anaerobic digester from the fermentation of organic waste
- Biogas can be combusted to produce energy
- PurposeEnergy, Inc. provided solution to a brewery in VT saving $0.7MM / year





$$\frac{\Delta S}{\Delta t} = \frac{k_{max} \times S \times X}{K_S + S}$$

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Problem statement

Assuming no prior knowledge of the nature of the imported substrate and using low-cost, commercially available instrumentation, develop a flow control algorithm in pseudocode that controls substrate addition at a rate that "tops off" the CHP power output (i.e. generates just enough biogas to maximize the output of the CHP).

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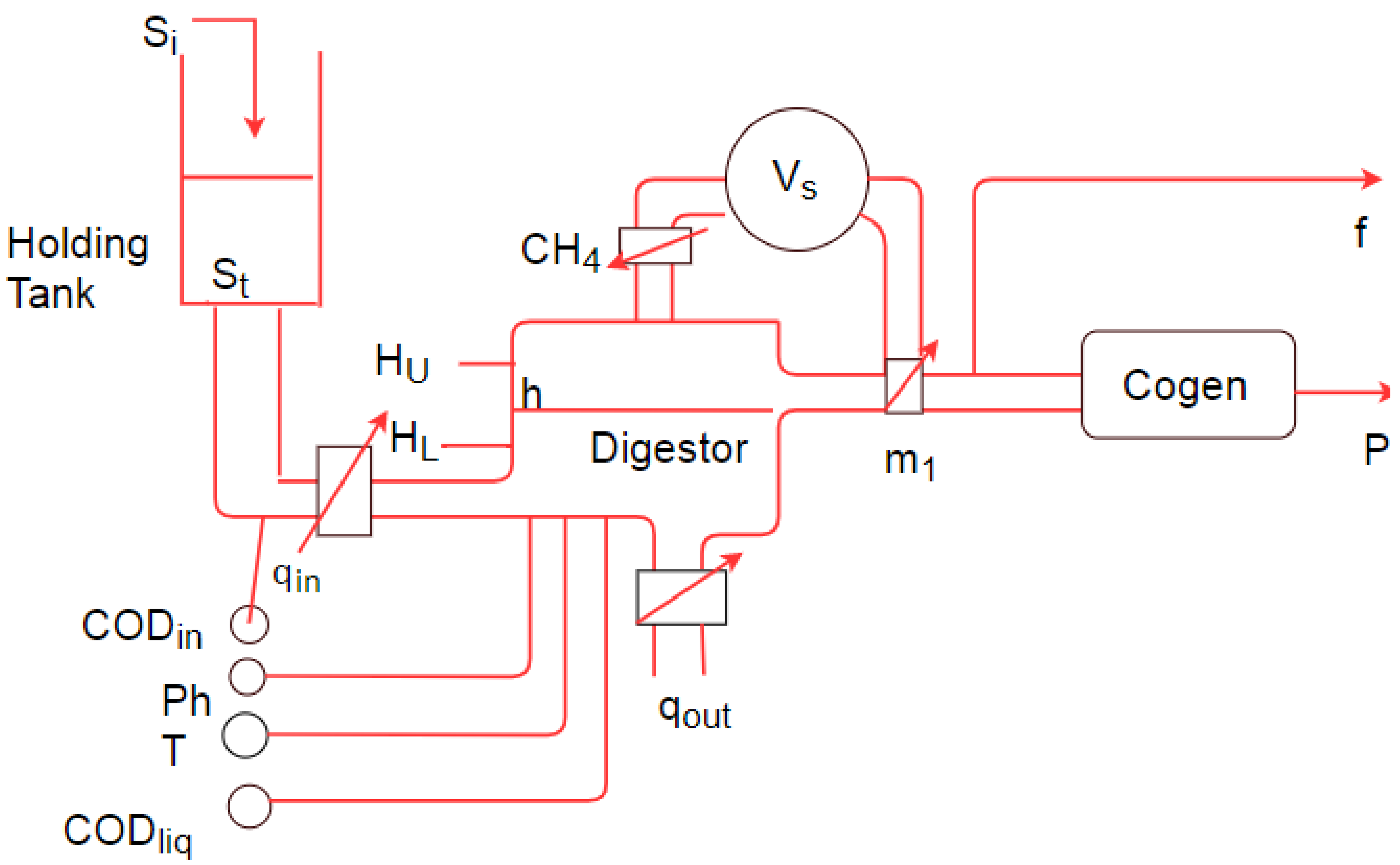
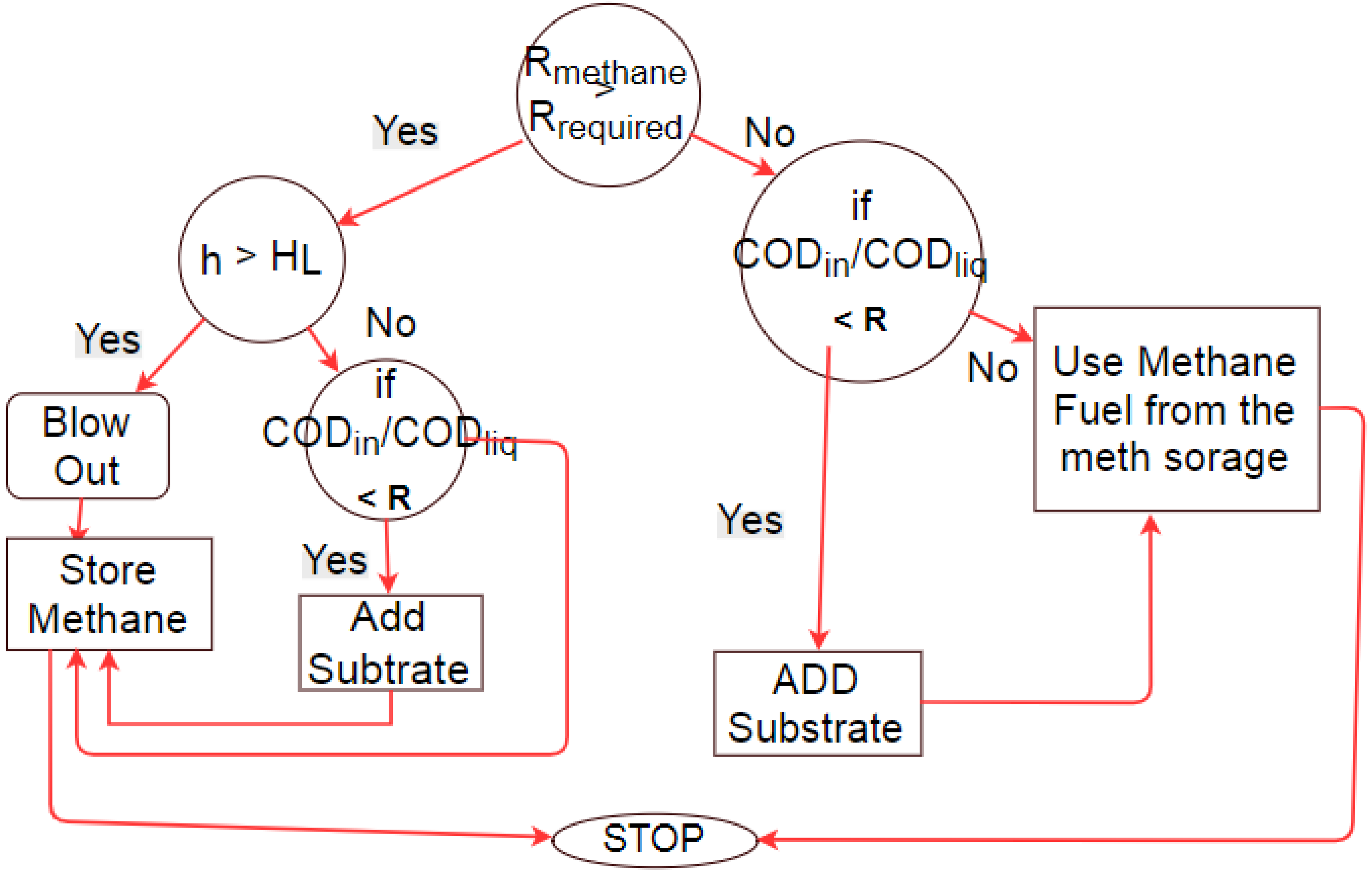
Process Flow and Decision Tree





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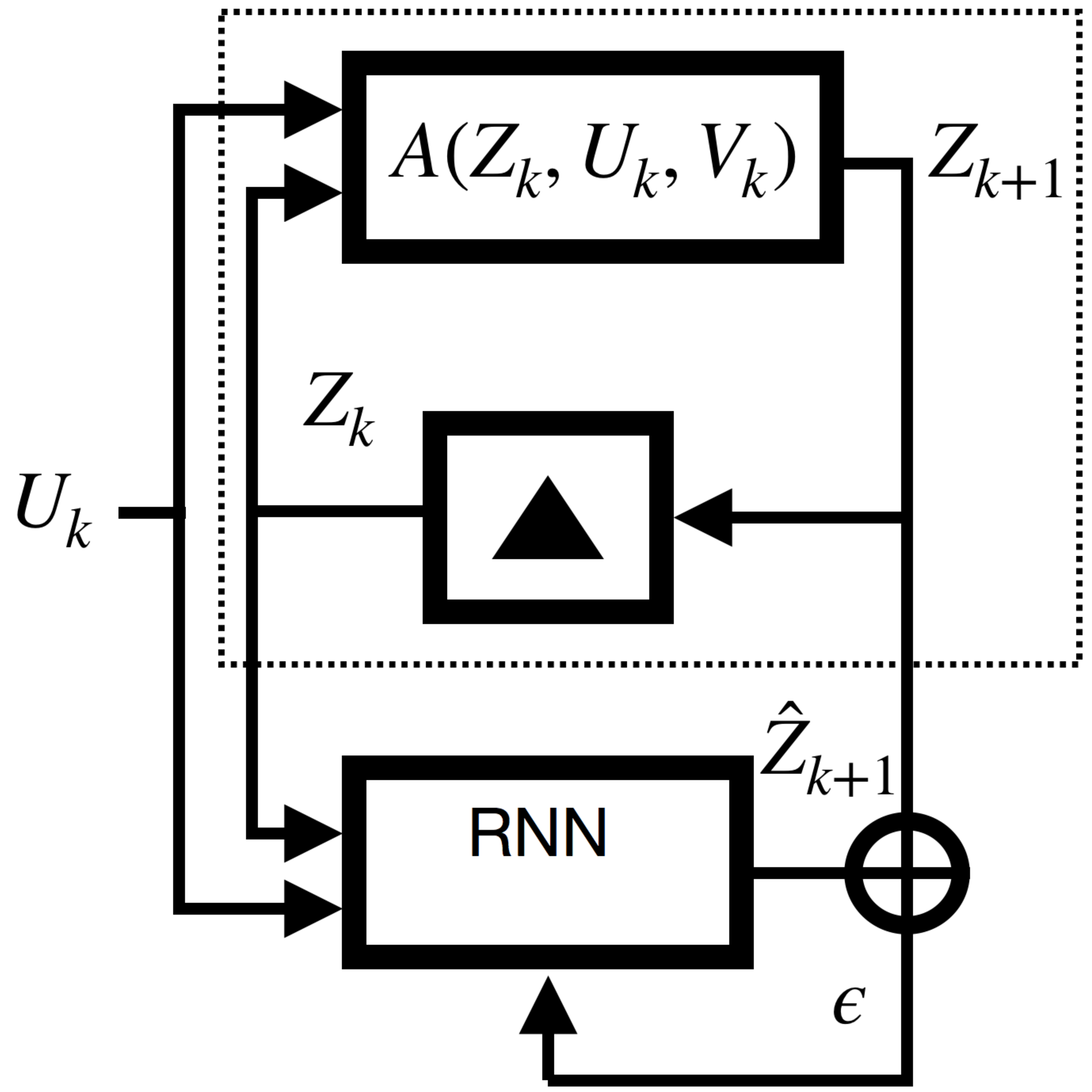
Stage 1



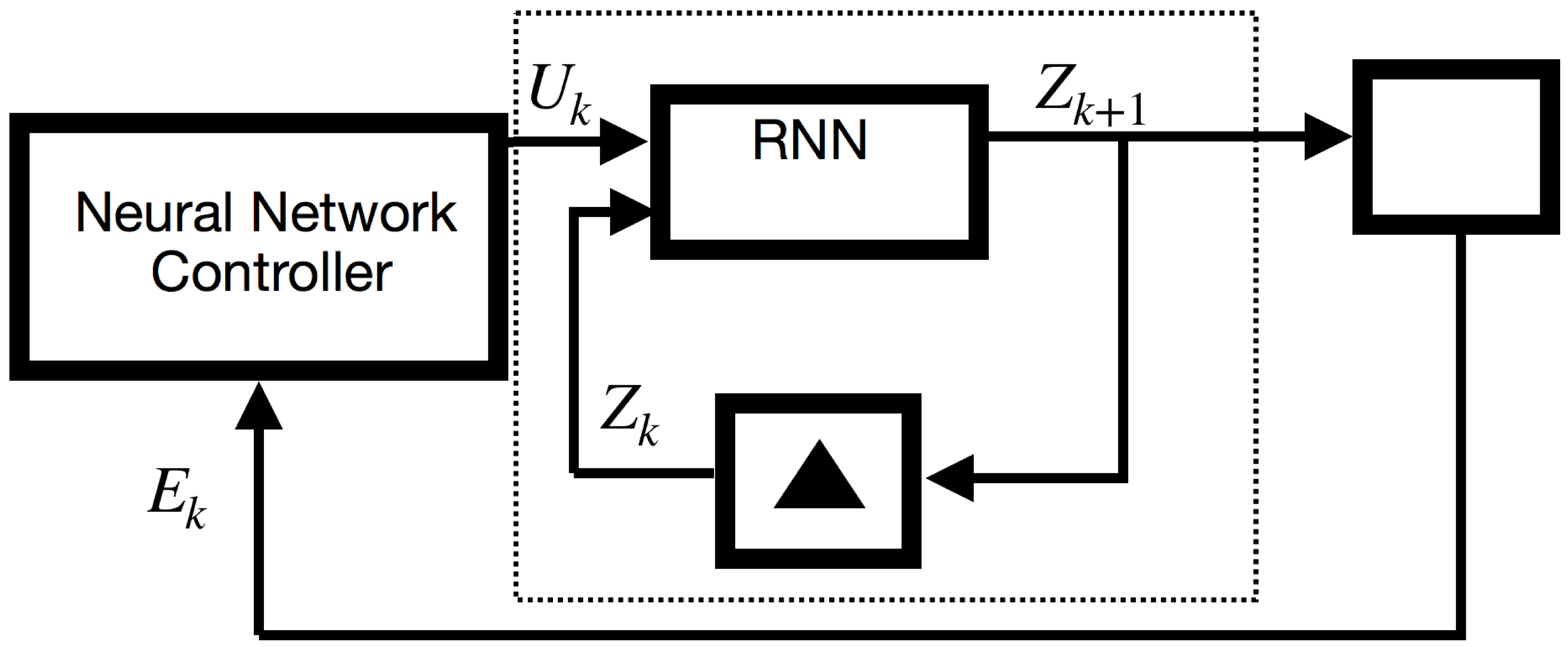
$$U_k = \{Ph_k,\ T_k,\ q_{in_k},\ q_{out_k},\ m_{1_k}\}$$

$$V_k = \{COD_{in_k},\ COD_{liq_k},\ Meth_k\}$$

$$Z_k = \{P_k,\ f_k,\ h_k,\ V_{s_k}\}$$

$$E = \sum_k (z_k - \hat{z}_k)^2\ \forall z_k \in Z_k$$

Stage 2



$$E_1(h) = \frac{1}{1 + e^{a(h+h_{low})}} + \frac{1}{1 + e^{-a(h-h_{high})}}$$ to make sure liquid level in digestion tank is within acceptable limits

$$E_2(V_{store}) = e^{b(V_s - V_{s_{max}})}$$ to make sure gas tank is not overflown

$$E_3(f) = f$$ to minimize flaring

$$E_4(P) = \frac{1}{1 + P}$$ to maximize power

$$E = \sum_k c1 \cdot E_1(h_k) + c2 \cdot E_2(V_{store_k}) + c3 \cdot E_3(f_k) + c4 \cdot E_4(P_k)$$

INAM = It’s Not About Me

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Computer Science

University of Illinois at Chicago
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Computer Science

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David Amirbekyan

Chemical Engineer

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Working in water treatment industry
with process analyzer experience.

Appendix

[1] Batstone, D.J.; Keller, J; Angelidaki, I.; Kalyuzhnyi, S.V.; Pavlostathis, S.G.; Rozzi, A.; Sanders, W.T.M.; Siegrist, H.; Vavilin, V.A. 2002. The IWA Anaerobic Digestion Model No 1 (ADM1). Water Science and Technology. 45(10):65-73.

[2] Borja, R.; Martín, A.; Rincón, B.; Raposo, F. 2003. Kinetics for Substrate Utilization and Methane Production during the Mesophilic Anerobic Digestion of Two Phases Olive Pomace (TOPO). Journal of Agriculture and Food Chemistry. 51(11):3390-3395.

[3] Nauman, E.B. 2008. Chemical Reactor Design, Optimization, and Scaleup. 2nd Edition. New York: John Wiley & Sons, Inc.

Appendix

[4] Nguyen, D.H.; Widrow, Bernard. 1990. Neural Networks for Self-Learning Control Systems. IEEE Control Systems Magazine. 10(3):18-23.

[5] Fitch, E.; Kshetry, H. 2017. Purpose Energy: Robust Anaerobic Digestion. Presented at: 2017 MIT Energy Hackathon; Cambridge, MA.

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Online Process Analyzer Examples and Sampling

COD Analyzers
LAR Process Analysis AG

CH_4 Analyzer
ABB

\+ Proper Sampling and Conditioning System