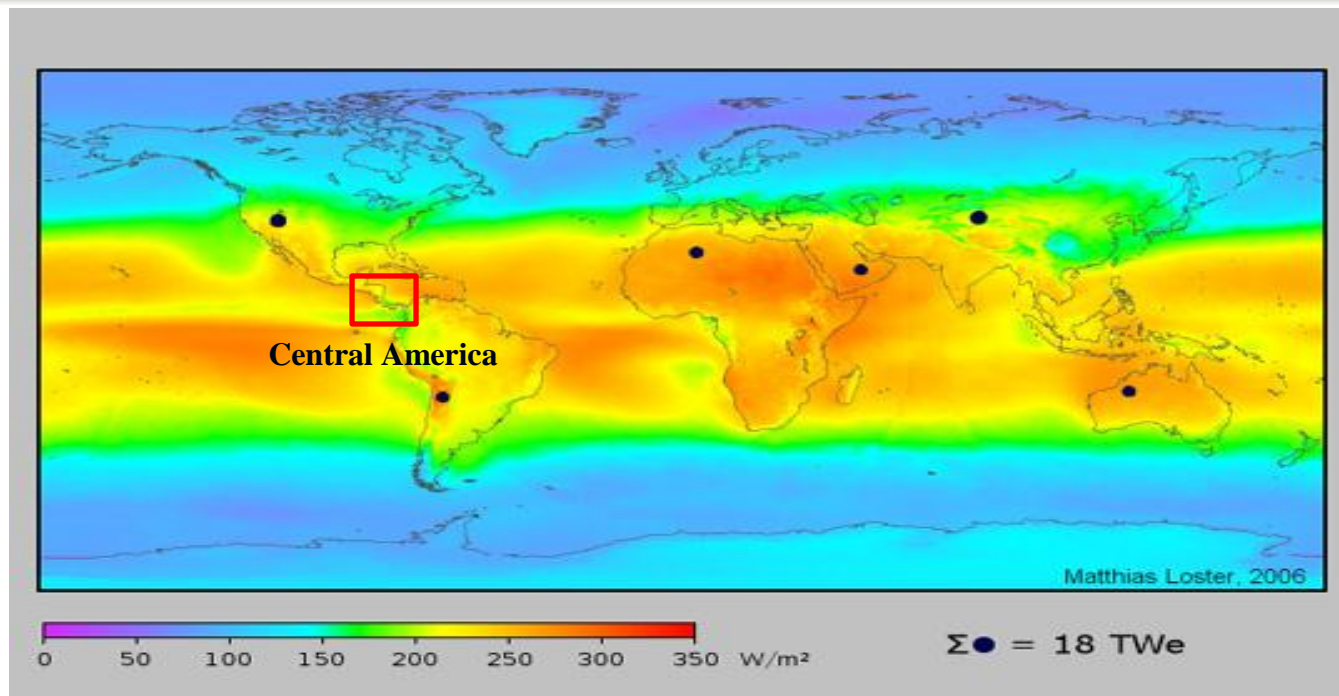


Small-Scale Solar-Biopower Generation For Rural Central America

Energy & Climate Partnership of the Americas
MSU/UCR Kickoff Seminar
March 2012

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❖ Advantages

- Theoretical: 1.76×10^5 TW striking Earth, Practical: 600 TW
- It is the cleanest energy source on the Earth.
- Solar energy reaching the earth is abundant.

❖ Disadvantages

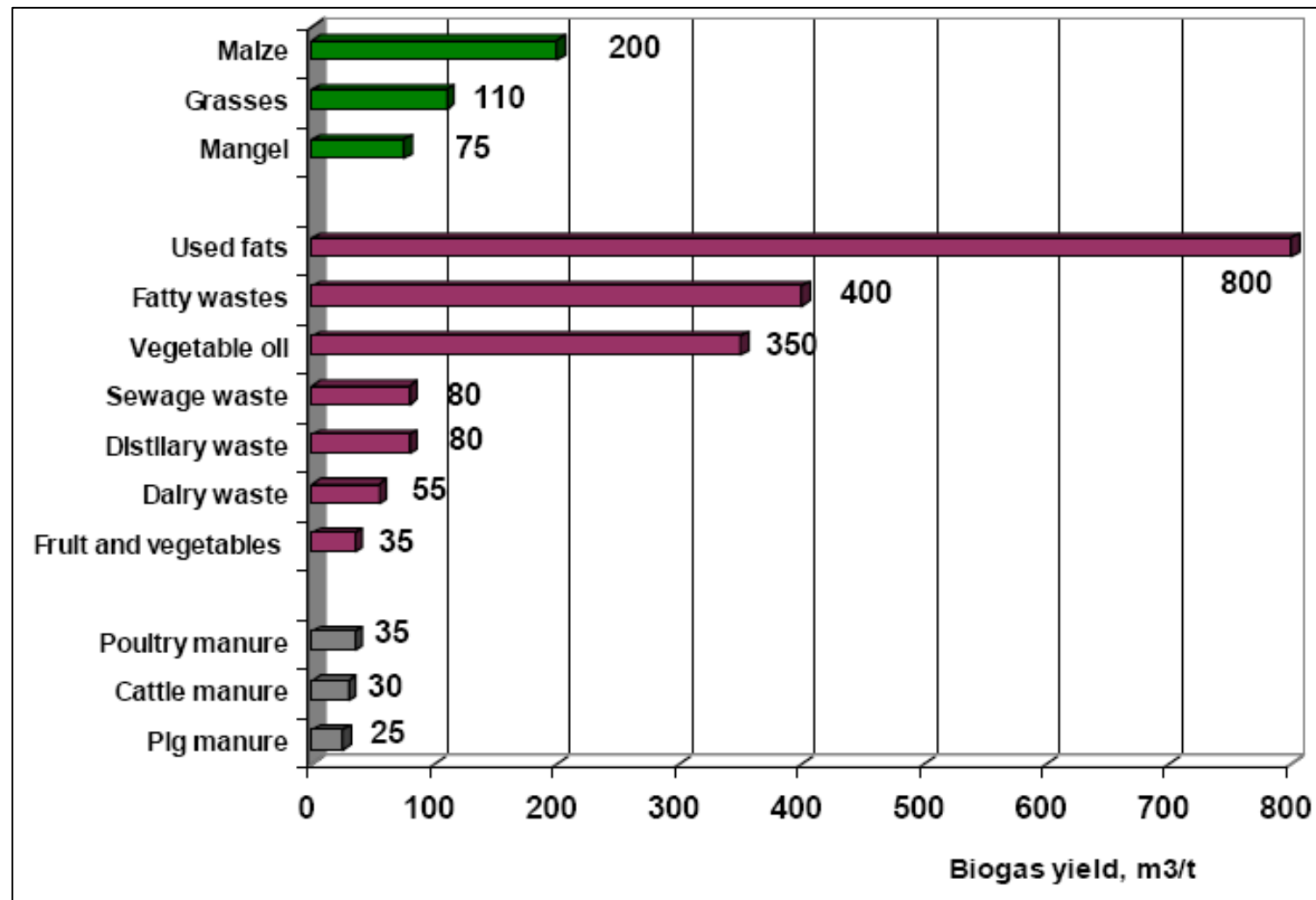
- Sun does not shine consistently.
- Solar energy is a diffuse source.
- It is difficult to collect, convert, and store solar energy.

- Agricultural residues available in Costa Rica

Residues	Total amount (metric ton dry matter per year)		Current treatment practices
	2006	Projection 2012	
Cattle manure	1,530,000	1,679,900	Only 20% of producers treat wastes, dried and composted
Swine manure	95,000	110,000	0.68% for production of energy and rest in agriculture, fertilizer (45.5%) food animal (53.1%) or other uses (0.7%).
Banana residues	158,000	132,000	Not used as energy source, 100% discarded or composted organic
Coffee residues	(pulp) 251,000 (husk) 25,000	(pulp) 262,000 (husk) 26,300	Pulp is used for composting, and husk is used for combustion
Sugarcane bagasse	1,290,000	1,518,200	95.3% dried and used as combustion, 4.7% non energetic
Pineapple residues	6,351,000	8,452,000	Combusted and soil improvement

- More than **600 MW** electricity per year could be potentially generated from this amount of waste streams through anaerobic digestion technology.

Feedstock Biogas Potential



❖ Advantages

- A biological process
- Reducing greenhouse gas emission
- Enhancing nutrient management

❖ Disadvantages

- Low efficiency of organic matter degradation
- Difficulty of power generation for small-medium operations



Completely Stirred Tank
Reactor (CSTR)



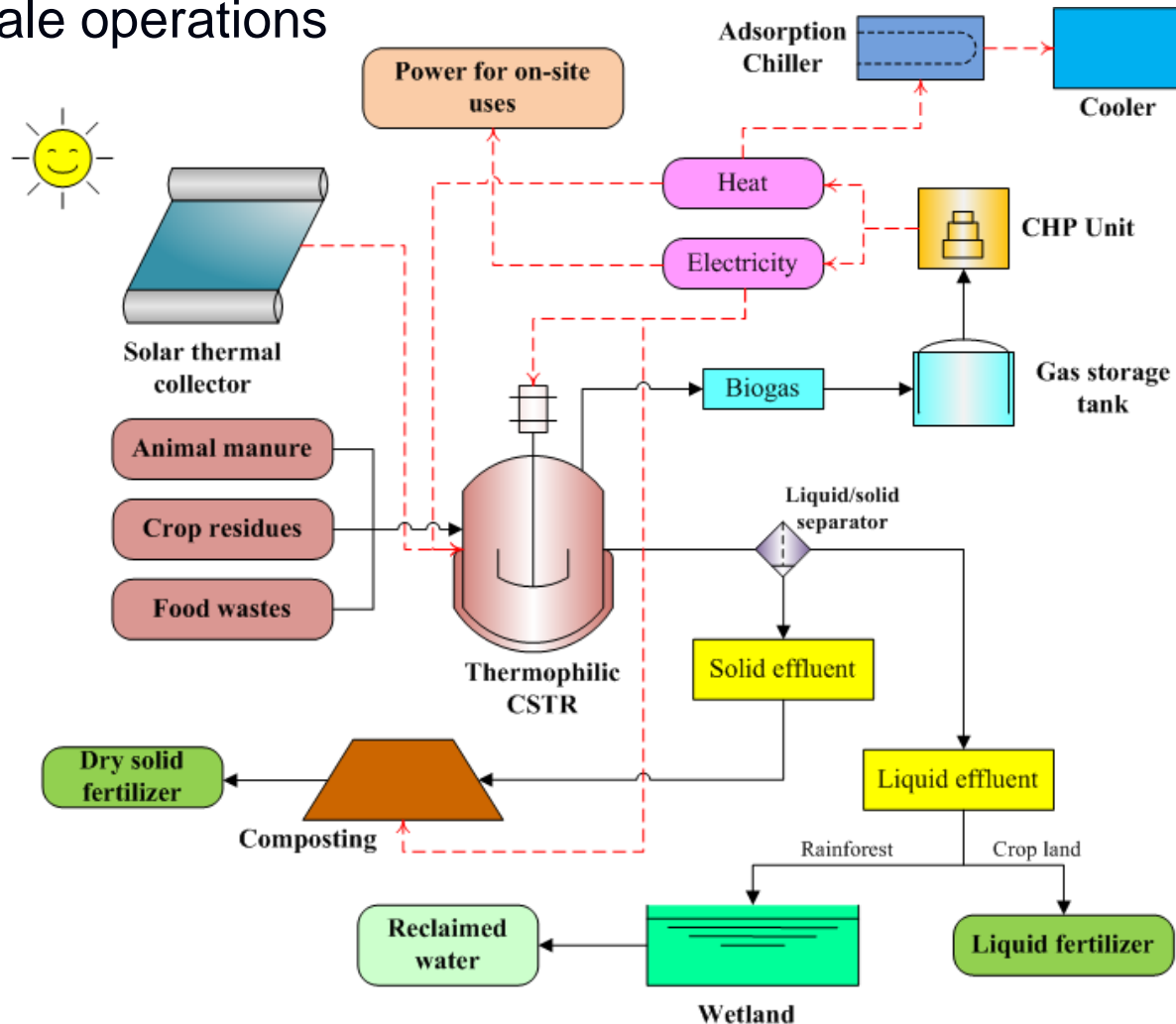
Anaerobic Sequence Batch
Reactor (ASBR)



Plug-flow digester

A Solar-Biopower Concept

Integrating wastes utilization with solar and biological technologies will create a novel self-sustainable clean energy generations system for small-medium scale operations



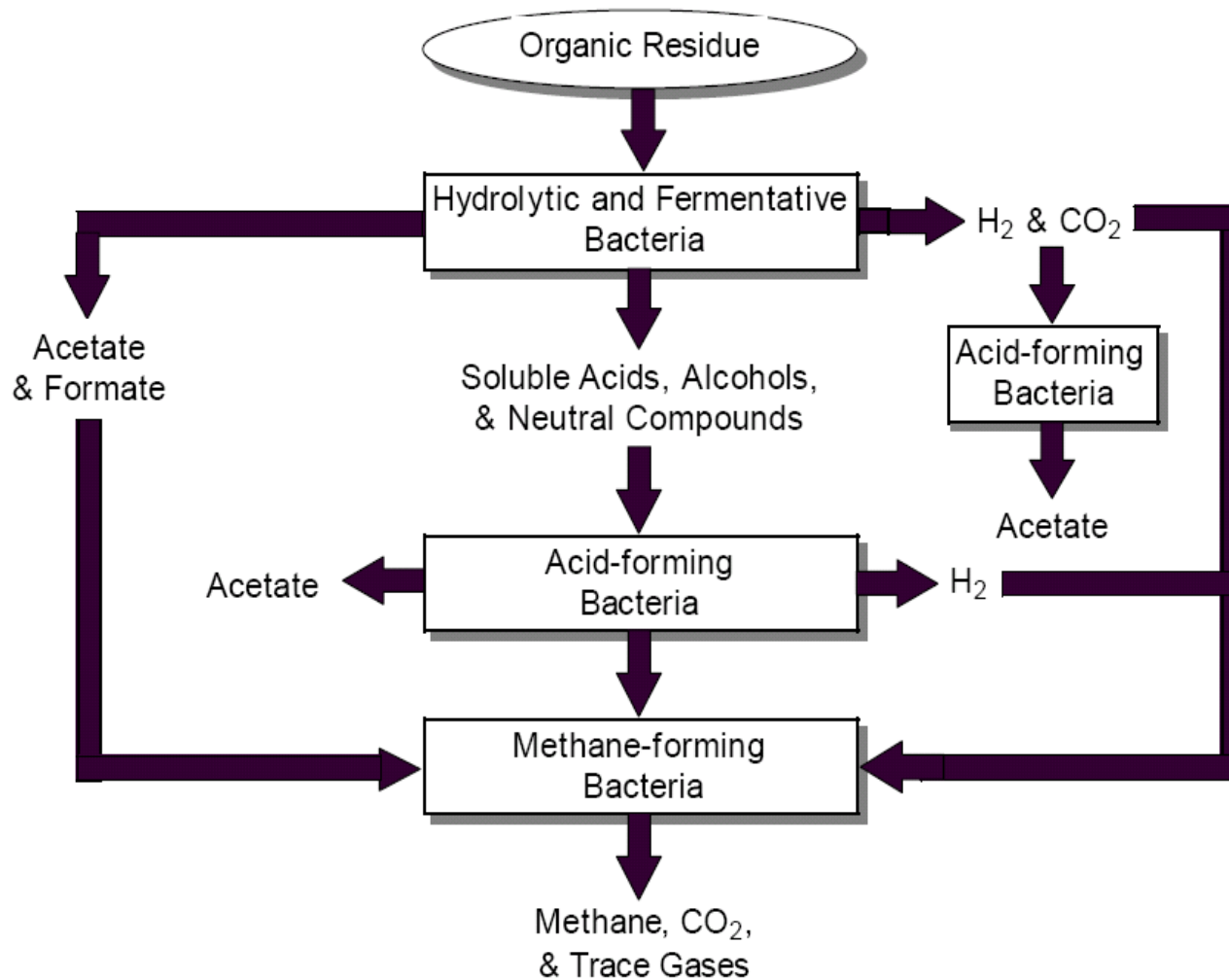
Benefits of system integration

❖ **Overcome the disadvantages of individual technologies**

- Unsteady energy flow for solar power generation
- Low efficiency of mesophilic anaerobic digestion on degradation of organic matter
- Higher energy requirement of thermophilic anaerobic digestion

❖ **Provide sufficient and stable energy for small-medium sized rural community**

- Solar energy utilization
- Improved efficiency of anaerobic digestion on degradation of organic matter
- Biogas energy as chemical storage – steady energy flow



20 L Bench-Scale Solar-Biopower System at MSU



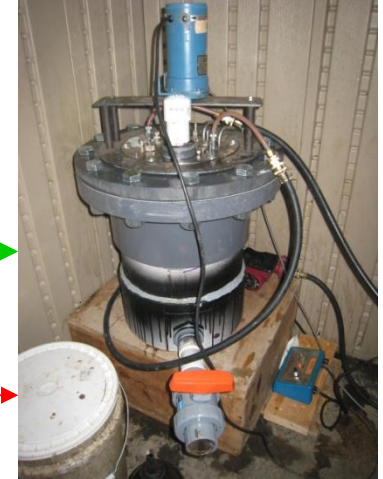
Evacuated tube solar collector



Solar thermal transfer system



Heat exchanger



CSTR anaerobic digester



Flat-plate solar collector

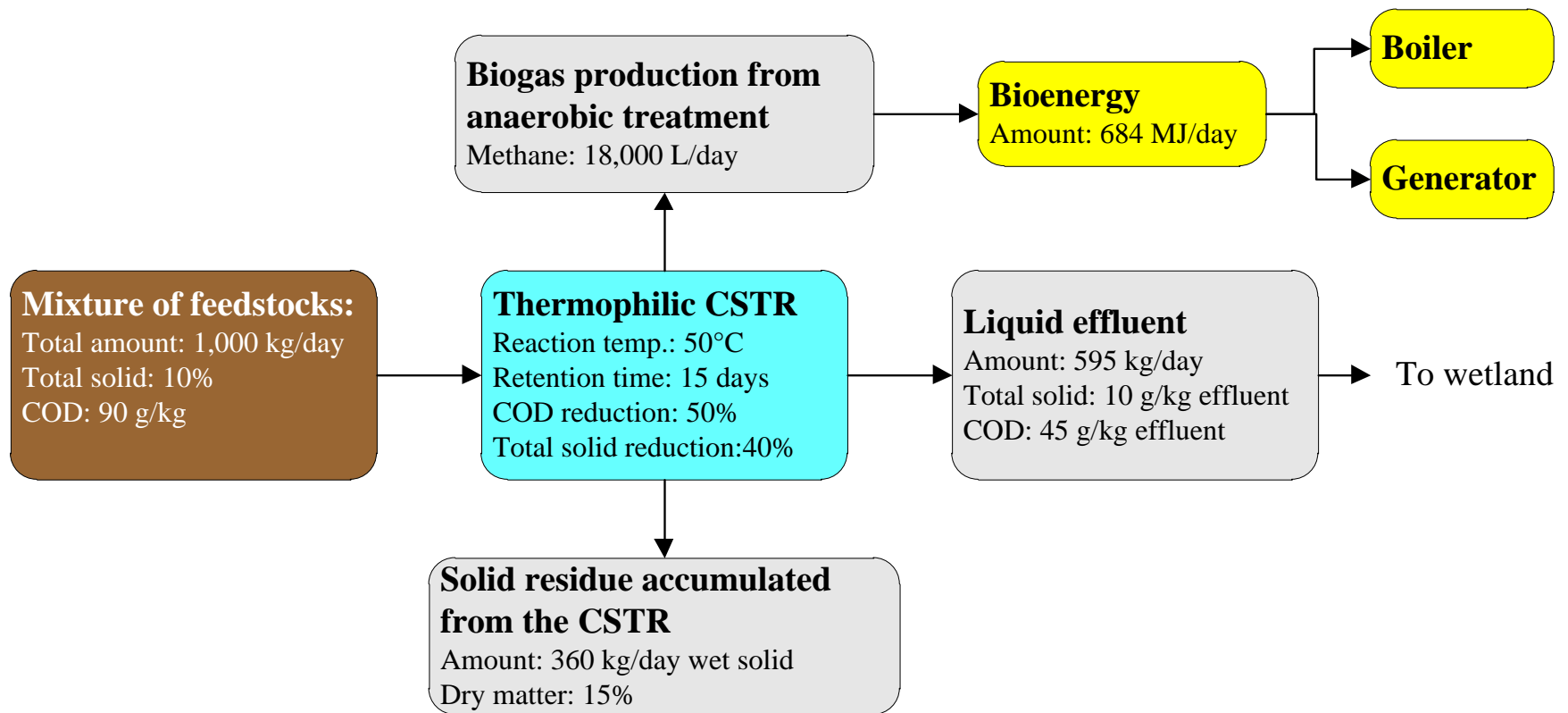


Control unit

— : Heat flow

- - - : System monitor and control

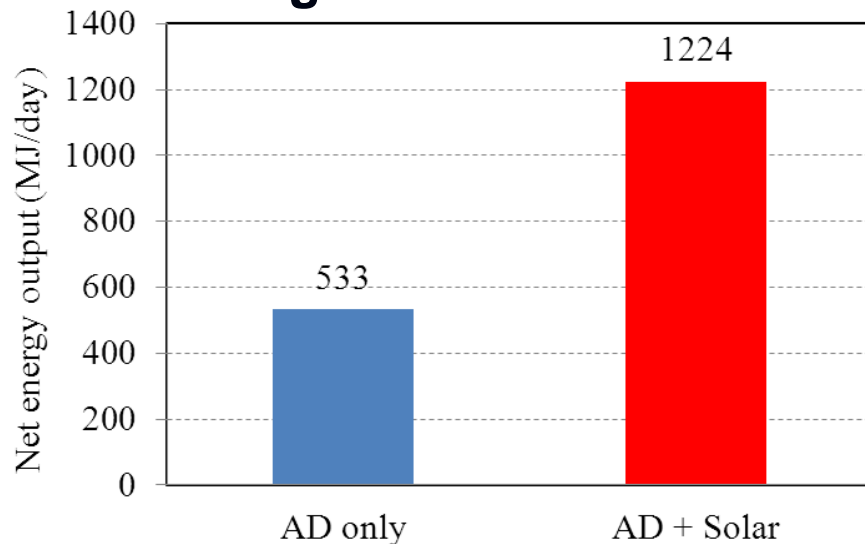
Predicted mass balance for the integrated solar-bio system on 1,000 kg of mixed sludge and food wastes



- The calculation of mass balance was based on the expected results that will be achieved by this project.
- A kg COD destroyed produces 350 L methane gas.

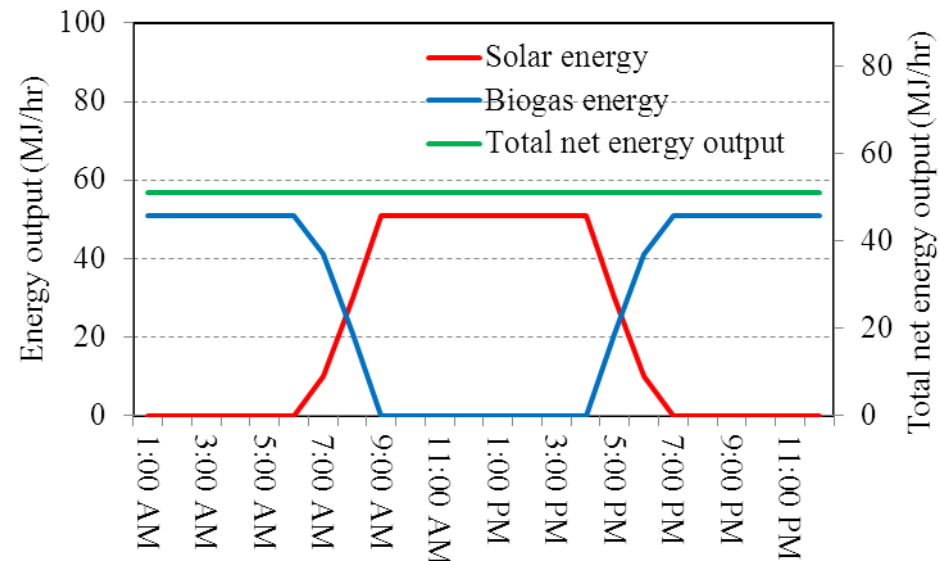
Potential energy generation based on 1,000 kg of mixed influent per day

Maximum daily net energy generation



Approximately 200% more net energy output (maximum) generated from solar-biopower system with the system under the optimal conditions.

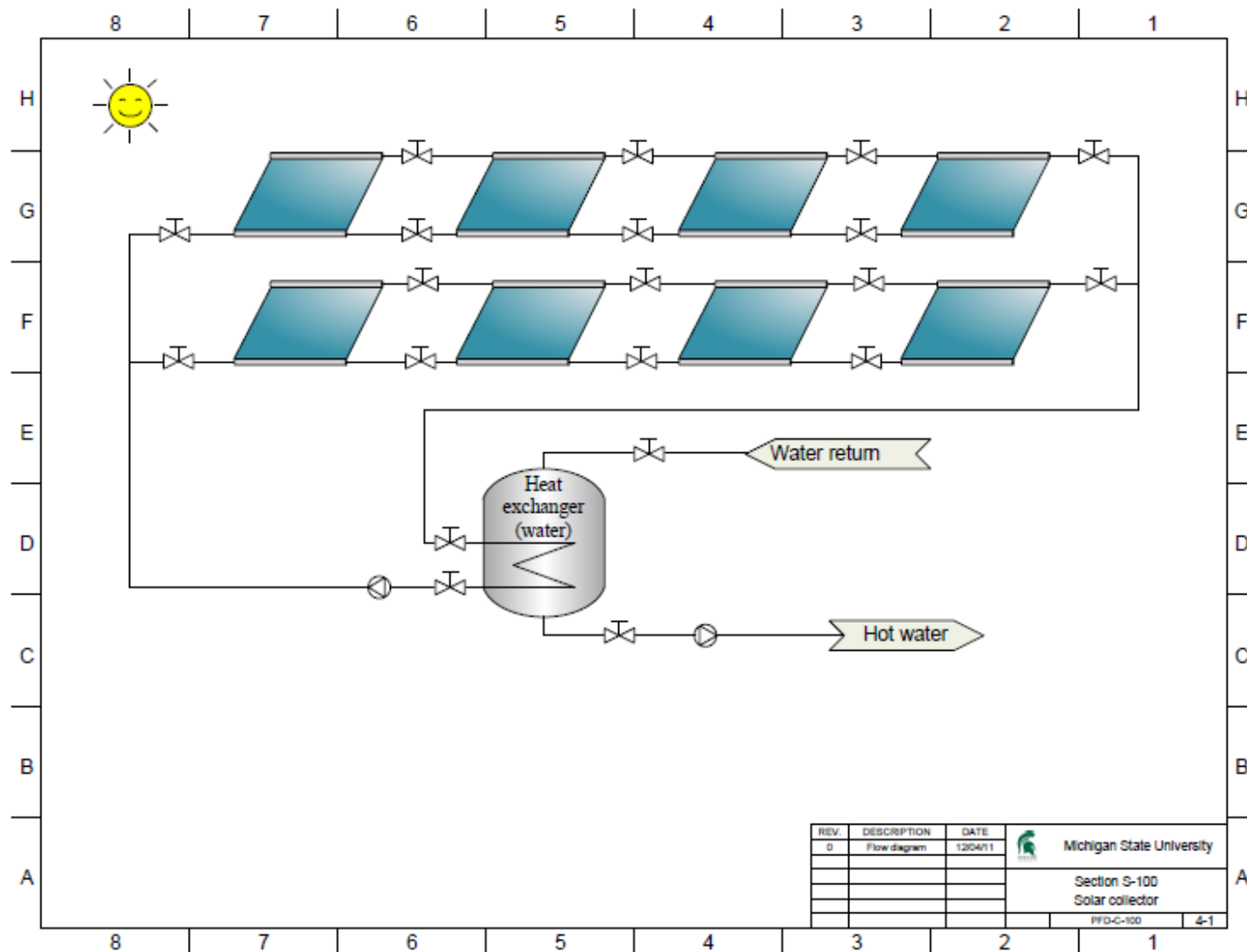
Time courses of maximum energy generation



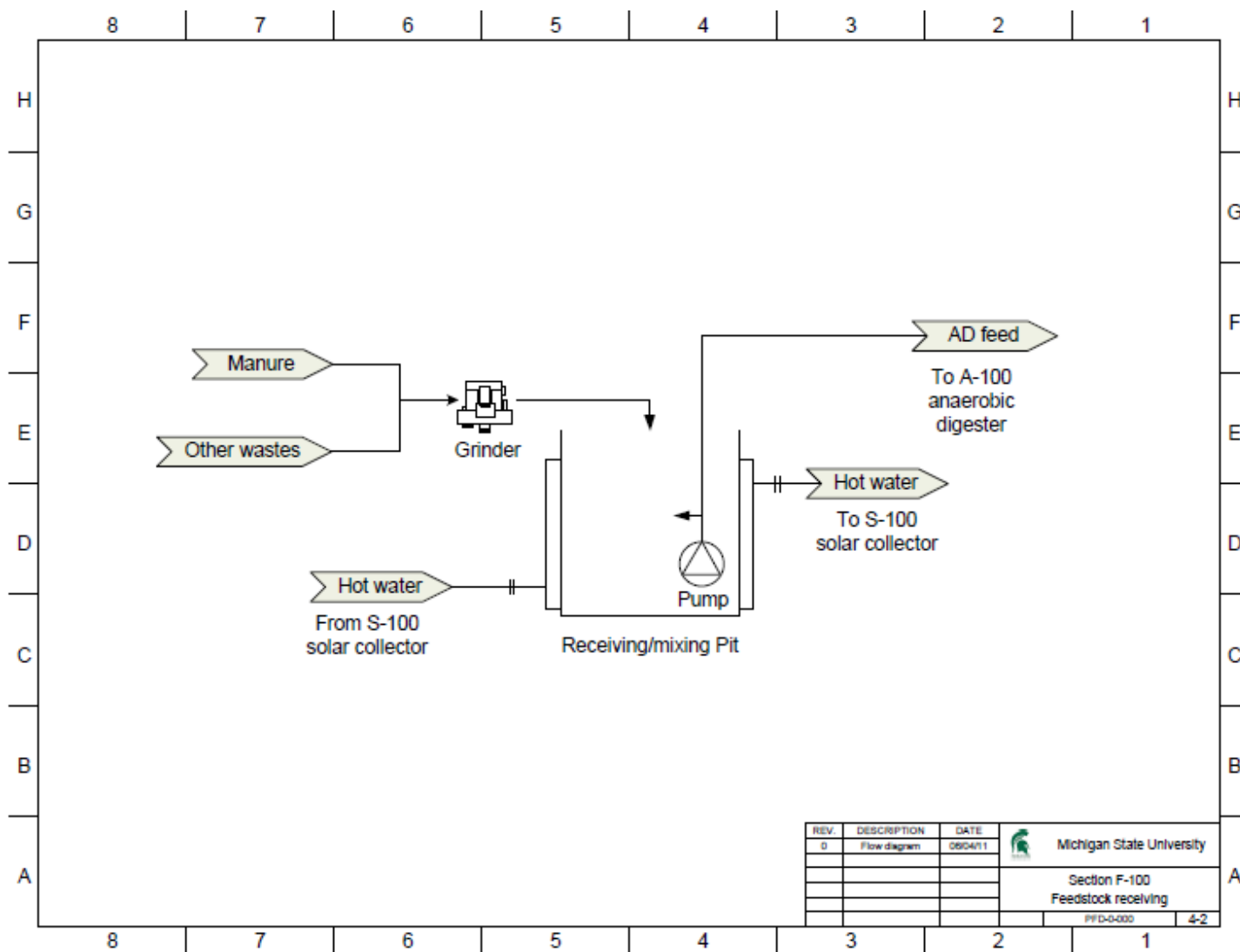
Time courses of potential net energy generation of solar-biopower system

❖ Major system components

- (8) 2x2 m flat-plate solar collector with support
- (1) 20 m³ anaerobic digester with a 50 m³ gas bag
- (1) 20 kW combined heating and power unit

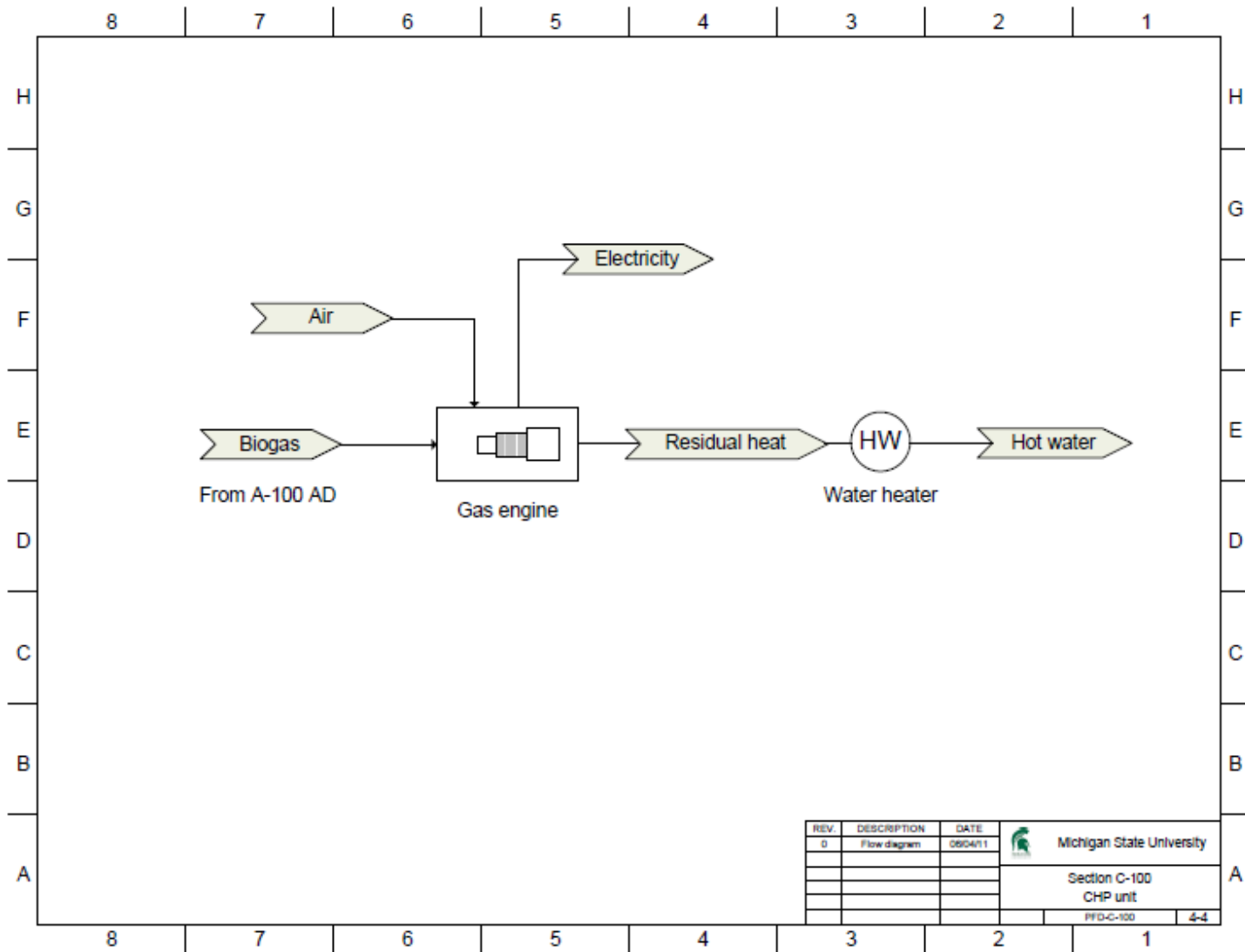


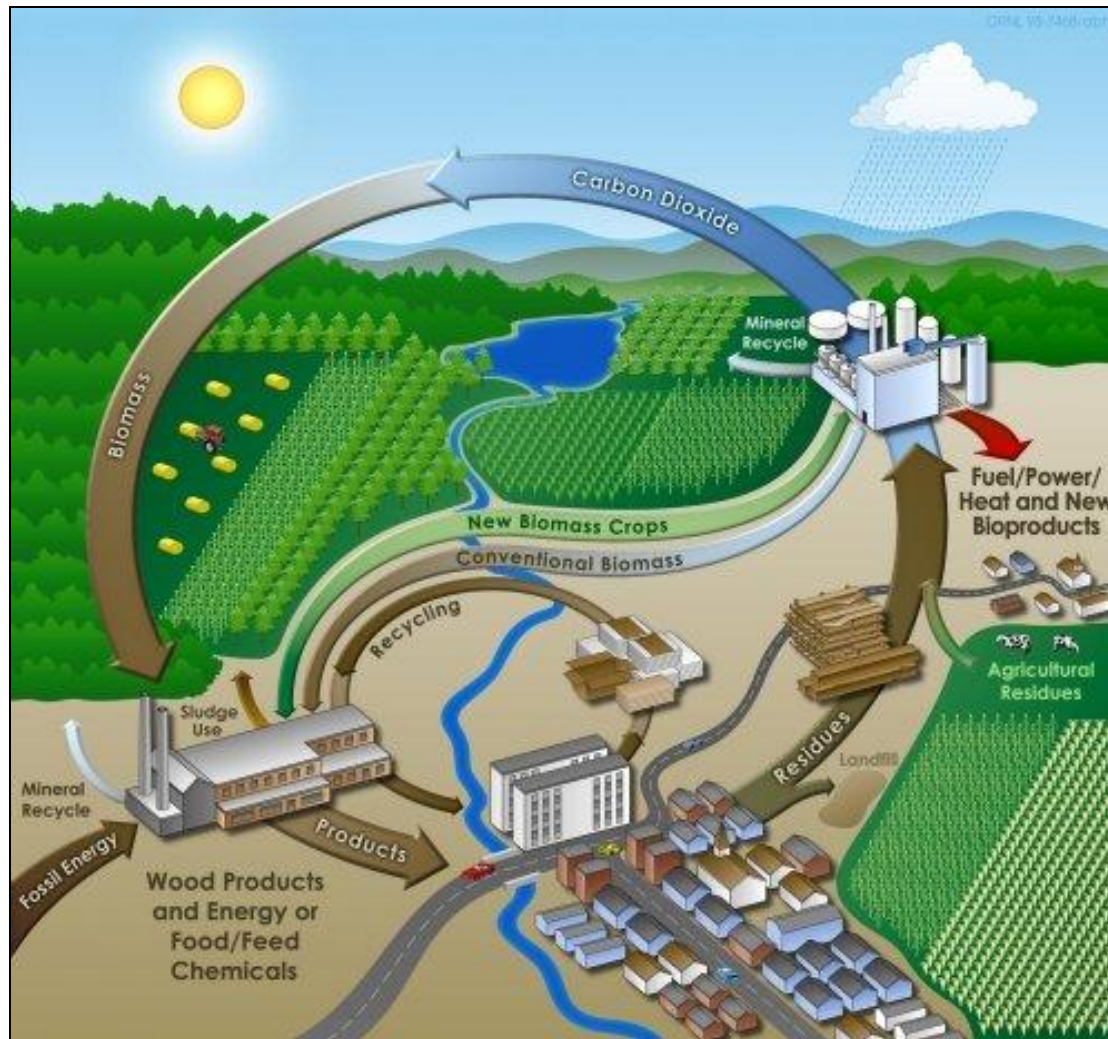
Feedstock Receiving Unit



MICHIGAN STATE
UNIVERSITY

Combined Heating and Power Unit





From: <http://www.usda.gov>

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