Dear Chemical Engineering Department Heads,

I am pleased to send you "The 2020-2021 TIChE National Chemical Engineering Student Design Competition" statement. We welcome participation by a team (or individual) of up to three undergraduate students from your department. Each department can submit no more than two teams. Each team must submit an Entry Form, provided in this attachment, before September 30, 2020 through e-mail indicated below.

Following is this year's challenge: "Bio-Residue Utilization for Circular City".

It is recommended that each team should review the rules on the following pages because it is important that all solutions strictly adhere to the Final Report Format.

All submissions must be submitted in an electronic format. Submissions must be no more than two documents -- totaling 100 or fewer pages of main text, with an allowable 100 pages of supplementary materials – in the PDF format. The requested format is a single PDF file -- the Adobe Acrobat program can be used to combine pages from different sources into one document.

Solutions must be submitted by e-mail (or hand delivery) no later than February 11, 2021. Please maintain a copy for your reference.

Questions relating to the substance of the design problem should be sent via e-mail directed to: TIChEdesign2020@gmail.com

Sincerely,

TIChE National Student Design Competition Working Committee

Thai Institute of Chemical Engineering and Applied Chemistry (TIChE)

Rules of Competition

Solutions will be graded on (a) substantial correctness of results and soundness of conclusions, (b) ingenuity and logic employed, (c) accuracy of computations, and (d) form of presentation. Accuracy of computations is intended to mean primarily freedom from mistakes; extreme precision is not necessary.

It is to be assumed that the statement of the problem contains all the pertinent data except for those available in handbooks and literature references. The use of textbooks, handbooks, journal articles, and lecture notes is permitted.

Students may use any available commercial or library computer programs in preparing their solutions. Students are warned, however, that physical property data built into such programs may differ from data given in the problem statement. In such cases, as with data from literature sources, values given in the problem statement are most applicable. Students using commercial or library computer programs or other solution aids should so state in their reports and include proper references and documentation. Judging, however, will be based on the overall suitability of the solutions, not on skills in manipulating computer programs.

The 2020-2021 National Chemical Engineering Student Design Competition is designed to be solved either by an individual undergraduate chemical engineering student working entirely alone, or a group of no more than three students working together. Solutions will be judged in two categories: individual and team.

There are, however, other academically sound approaches to using the problem, and it is expected that some academic instructors may use the problem as classroom material. The following confidentiality rules therefore apply:

1. For individual students or teams whose solutions may be considered for the competition: The problem may not be discussed with anyone (students, faculty, or others, in or out of class) before or during the period allowed for solutions. Discussion with faculty and students at that department is permitted only after complete final reports have been submitted to the TIChE.

2. For students whose solutions are not intended for the competition: Discussion with faculty and with other students at that department who are not participating in the contest is permitted.

3. For all students: The problem may not be discussed with students or faculty from other departments, or with individuals in the same institution who are still working on the problem for the competition, until after February 19, 2021. This is particularly important in cases where neighboring institutions may be using different schedules.

Submission of a solution for the competition implies strict adherence to the following conditions: (Failure to comply will result in solutions being returned to the appropriate Department Head for revision. Revised submissions must meet the original deadline.)

ELIGIBILITY

Entries must be submitted either by individuals or by teams of no more than three undergraduate students. Each team member must meet all eligibility requirements.

Each department should entry, not to exceed two teams, and submit them per the instructions below.

REPORT FORMAT

The body of the report must be suitable for reproduction, that is, computer-generated and in a printable format. Tables, supporting calculations and other appendix materials may be handwritten.

The solution itself must bear no reference to the students' names and institution by which it might be identified. Please expunge all such references to the degree possible.

Final submission of solutions to TIChE must be in electronic format (PDF). The main text must be 100 pages or less, and an additional 100 page or less is allowable for supplementary material. The final submission to TIChE must consist of 1 or 2 electronic files.

SENDING THE SOLUTION TO TIChE

There should not be any variation in form or content between the solution submitted to the team advisor (or department head) and that sent to TIChE. The team advisor is asked to maintain the original manuscript(s).

The electronic PDF file, accompanied by its corresponding entry form, shall be e-mail to TIChEdesign2020@gmail.com or hand delivery (or by post) to:

TIChE National Student Design Competition Working Committee
Thai Institute of Chemical Engineering and Applied Chemistry (TIChE)
Department of Chemical Engineering, Faculty of Engineering
Chulalongkorn University, Phayathai Road,
Pathumwan, Bangkok 10330

DEADLINE: Entries must be no later than midnight of February 19, 2021.

National Chemical Engineering Student Design Competition

Year 2020-2021

Bio-Residue Utilization for Circular City

Background and Motivation

Due to the inefficient use of natural resources including fossil fuel, leading to resources depletion and environmental damage, the world is now facing climate change and the ambient temperature keeps on rising. To mitigate the problem, the new concept of Circular Economy has been introduced. The concept is aimed to provide sustainable ways to produce goods and services by increasing the conversion efficiency at all stages of the product economy and limiting the environmental impact and waste of resources. The Circular Economy is a global strategy that utilizes the principle of life cycle assessment, green economy, industrial ecology, and eco-design to build the sustainable world for future generation.

Thai government encourages all economic sectors to adopt new economy model, the so-called Bio Economy – Circular Economy - Green Economy Model, (BCG Model) for developing their new business. The model focuses on the economy with

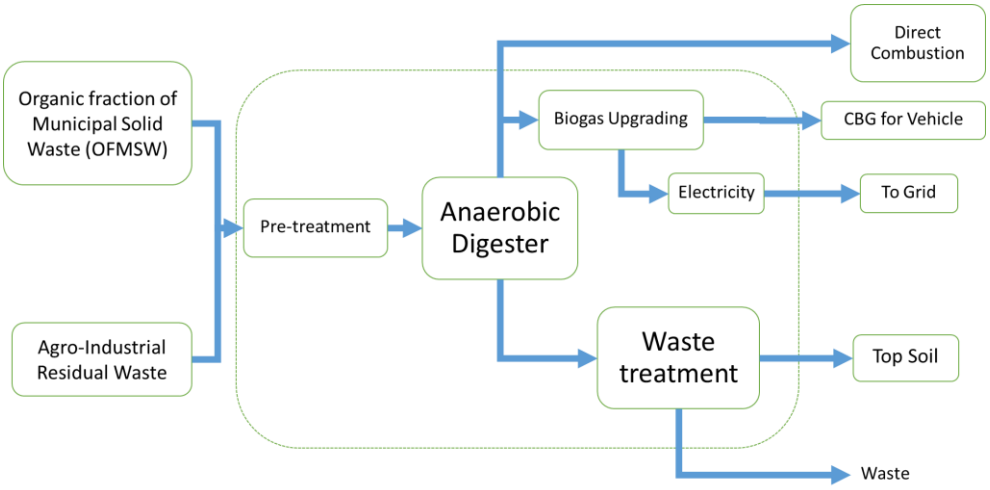
- *effective bio-resources utilization (Bio Economy),*
- *closed loop utilization of resources & residues (Circular Economy) and*
- *improved human well-being, social equity and reducing environmental impact (Green Economy)*

This project is considered to be a prototype of community development that implements the BCG model and demonstrates the industry-community symbiosis by focusing on a renewable energy biogas plant which has its input from municipal wastes and agro-industrial residues. The energy output of the plant can then be utilized and/or produce income for the community.

Process Description

Biogas production relies on anaerobic organic decomposition processes, which is either wet or dry process. The biogas is humid and mainly composes of methane, carbon dioxide and water. It also consists of hydrogen sulfide of which quantity depends on the type of wastes fed in the process.

Figure 1. Block diagram of biogas production and its utilization



There are several ways of biogas utilization. The followings are examples;

- Biogas as a fuel for local industries (to be used for direct combustion).
- Biogas (as a fuel) to produce electricity (sell to the EGAT grid: for more information http://www.ppa.egat.co.th/ppadx/)
- Biogas upgrading to compressed biogas or CBG (to be used for automobiles).

Since the specification of biogas depends greatly on its application, the designed plant needs to have treatment units for improving the quality to match with its end users' requirement. Besides, the plant must comply with government laws and regulations. Wastes from digestion and quality enhancement processes shall also be treated.

Project Objectives

To develop a sustainable city for the designated community, you are requested to design a biogas plant by using organic fraction of municipal solid wastes (MSW) as a main raw material and/or residuals from local agricultural industries as a supplemental raw material if appropriate.

This biogas plant is not only to provide energy for the community but also to get rid of the community wastes in the useful way. Moreover, the plant will help reduce the greenhouse gases (GHGs) emission of the community. To do so, you need to select an appropriate technology or more to convert the raw materials into biogas and to treat it to match its application. And you are also needed to propose the appropriate and worth-investment ways of handling and managing the raw materials, the possible and worth-investment applications of the energy produced from the plant. Additionally, to prove that this plant is worth in environmental perspective, reduction of GHGs emission amount to atmosphere by having this plant should be calculated.

You will need to develop a process design with any assumptions you may consider necessary, equipment sizing, a practical plot plan and any other relevant information listed in Deliverables. Finally, an economic feasibility study of the plant shall be evaluated.

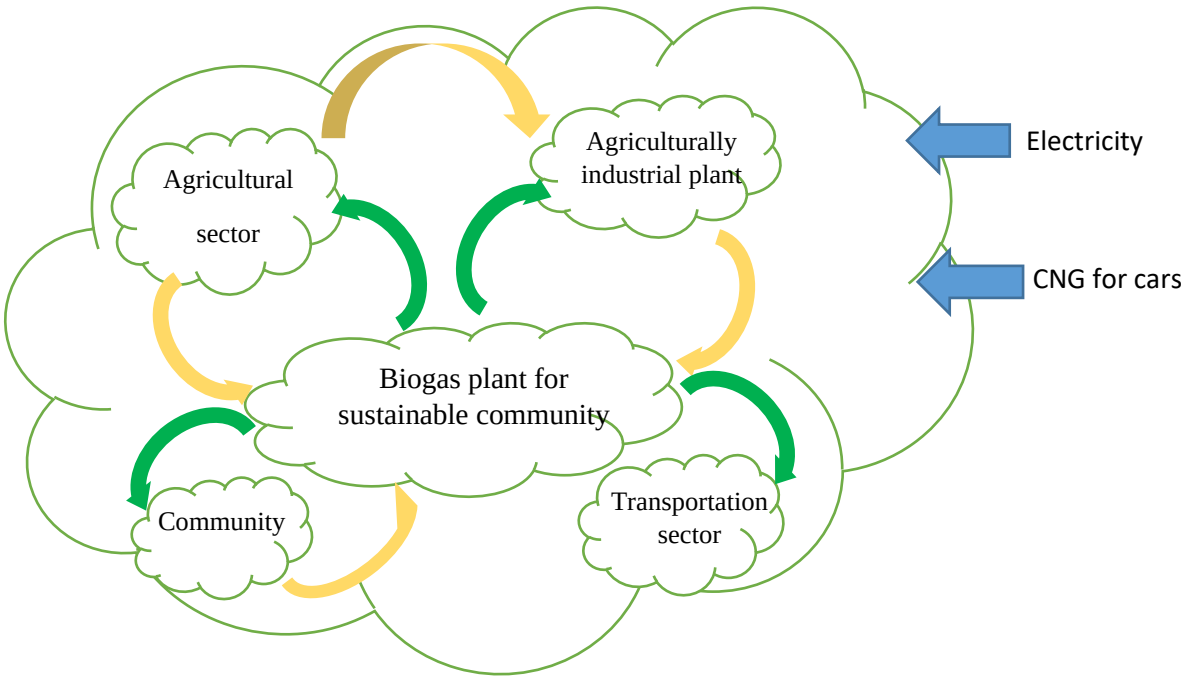


Figure 2. Community towards sustainable city

Design Requirement

A city in consideration has a population of 600,000 people. Currently, the city has a system for collecting and classifying the wastes. From the data, the amount of collected waste is up to 600 tons per day. The composition of the waste is shown in Table 1. It was found that 48.97% of MSW was organic fraction (OFMSW) with low heating value (LHV) of 5,500 kcal/kg. For the rest of the wastes, the city can manage to earn the incomes for supporting the waste management system. The expense for transporting OFMSW from the waste separation facility to the biogas plant is 100 Baht per ton. The Provincial Electricity Authority (PEA) reports that the household electricity consumption of the city is 9,300 MWh per month. And 90% of the electricity is produced by a hydropower plant. The city supplies 1 ton of CNG for automobile annually.

At the city's perimeter, there are 5,000 Rais of agricultural land. The main crop produced on the land is cassava, which is fed as a feedstock to an existing modified starch plant. The capacity of the plant is 500 tons per day, 300 days a year. The plant currently has the residual which is 800 tons per day of cassava waste. The plant offers free cassava waste to you at its backyard. Loading, Unloading, and transportation of those wastes, which costs 100 Baht per ton, is on your bill.

There is a land (plot) of 50 Rais suitable for constructing the biogas plant next to the starch plant. The selling price of the land is 200,000 Baht per Rai.

For your consideration, a potential customer requires a gas fuel through a pipeline for his burner at 250 mbarg. You could also sell the energy in form of electricity through internal combustion engine(s). For the selling price of electricity, please see the government's criteria in the Appendix. Besides, biogas for automobiles in the form of compressed biogas (CBG) must have at least 80% of methane in composition at the pressure of 250 barg.

Deliverables

The report should have contents as following.

- Letter of Transmittal
- Cover Page
- Table of Contents
- Introduction /Conceptual Design include Block Diagram
- Overall Material and Energy Balance
- Process Description
- Process Flow Diagram
- Preliminary Piping and Instrument Diagram (optional)
- Utility Requirements
- Equipment List
- Equipment Specification
- Preliminary Plot Plan
- Safety, Health and Environmental Considerations
- Investment Cost Summary
- GHG Calculation
- Economic Analysis
- Conclusions and Recommendations
- Acknowledgements
- Bibliography
- Appendix / Calculation and Sizing Spreadsheet

Appendix

- The low heating value of biogas with 60% methane = 4400 kcal/Nm3 biogas
- The price of electricity is 5.50 Baht/kWh
- The price of CNG is 16 Baht/kg
- The government sets the criteria for buying electricity from community power plant by FIT model as follows:
    - The period of selling electricity is 20 years.
    - Power plants with capacity less than 1.5 MW, the selling price is 5.50 Baht /kWh
    - Power plants with capacity between 1.5 and 3.0 MW, the selling price is 4.50 Baht /kWh
- The price of wood chip as received, included VAT 7%, delivered to the plant is 950 Baht/ton. Its low heating value as received is 4,500 kcal/kg.
- Other information from: https://www.diw.go.th/km/safety/pdf/biogas_2.pdf
- Standard water discharge from a plant 2560 B.E. announced by June 7, 2017 (https://www.diw.go.th/hawk/news/11.PDF)
- Criteria, procedure and condition for considering the temporary use of industrial wastewater on the agricultural land during the drought announced by March 2, 2020. (https://www.diw.go.th/hawk/law/env/%E0%B8%9B%E0%B8%A3%E0%B8%B0%E0%B8%81%E0%B8%B2%E0%B8%A8%E0%B8%AD%E0%B8%81.%E0%B8%AB%E0%B8%A5%E0%B8%B1%E0%B8%81%E0%B9%80%E0%B8%81%E0%B8%93%E0%B8%91%E0%B9%8C%E0%B8%9E%E0%B8%B7%E0%B9%89%E0%B8%99%E0%B8%97%E0%B8%B5%E0%B9%88%E0%B9%80%E0%B8%81%E0%B8%A9%E0%B8%95%E0%B8%A32563.pdf)
- The regulation for the quantity of contaminants in air discharge from power plant B.E.2547 announced by Sept. 28, 2004 (https://www.diw.go.th/hawk/law/air/A7.pdf).

Table 1. The composition of municipal wastes

(Source: Table 1-2: https://www.dede.go.th/article_attach/h_waste.pdf)

Percent of fresh municipal waste		
List of items	Wet basis	% humidity
Food & vegetable wastes	53.49	88.3
Plastic	20.12	
Paper	8.95	12.0
Glass	5.02	
Metal	1.80	
Others such as bone /seashell / hazard waste /battery, etc.	10.62	
Total	100	

MSW was produced 0.57 kg per person per day

Table 2. Biogas composition

CH_4	50 - 70 %(v/v)
CO_2	20 - 50 %(v/v)
H_2O (vapor)	0 -10 %(v/v)
N_2	0 - 5 %(v/v)
O_2	0 - 2 %(v/v)
NH_3	0 - 1 %(v/v)
H_2S	50 - 5,000 ppm

In your design, the designers can specify the main composition, CH_4, CO_2, H_2O (vapor), H_2S, of the biogas by yourself.

Table 3. Specification of the biogas according to applications

Applications	Specification		
	H_2S	CO_2	H_2O
Household (Cooking Gas)	No requirement but suggest to remove it	No requirement	No requirement
Industrial Combustion	< 1000 ppm.	No requirement	No requirement but suggest to reduce its concentration to prolong equipment life and safety
Combined Heat and Power, CHP	< 1000 ppm.	No requirement	No requirement but suggest to reduce its concentration to prolong equipment life and safety
Automobile Engine	< 100 ppm.	No requirement but suggest to reduce in order to increase the heating value	To be eliminated according to the standards (Water dew point = T- 5) T = air temperature ^oC