Cell phone application for sizing anaerobic digesters and computing energy production, biogas and methane yields

Mohamed Samer[1*], Badr A. Mohamed[1,2], Shehab S. Abdeen[3], Khaled M. Abdelbary[1]

(1. Department of Agricultural Engineering, Faculty of Agriculture, Cairo University, 1 El-Gamaa Street, 12613 Giza, Egypt
2. Department of Civil Engineering, University of British Columbia, 6250 Applied Science Ln #2002, Vancouver, BC V6T 1Z4, Canada
3. Rahma Software and Electronics Company Limited, Hadayek El-Ahram, El-Geish Street, 12556 Giza, Egypt)

Abstract: To perform the calculations required for sizing anaerobic digesters and computing energy production and biogas and methane yields, various procedures should be conducted; this requires time and effort, with the risk of making mistakes. The objective of this study was to create a tool to aid users and specialists in managing these computations by offering an application which can be installed on cell phones. A mathematical model was developed to perform the calculations. Then, a flowchart was created, and the mathematical model was incorporated into the flowchart. Then, MIT App Inventor was used to configure application software by combining the flowchart and the mathematical model and making the user interface. Data were acquired from governmental institutions, livestock farms having biogas units, biogas plants, non-governmental organizations (NGOs), and literature. The data acquired were used to perform the calculations through applying the conventional method to produce results which were compared with results produced by the developed application software. The results of the conventional method and the application software were identical. The developed cell phone application can size the anaerobic digesters and compute the energy production and biogas and methane yields from livestock manure and agricultural crop residues.

Keywords: biogas, cell phone application, anaerobic digesters, methane production, livestock manure, agricultural wastes.

Citation: Samer, M., B. A. Mohamed, S. S. Abdeen, and K. Abdelbary. 2023. Cell phone application for sizing anaerobic digesters and computing energy production, biogas and methane yields. Agricultural Engineering International: CIGR Journal, 25(4):266-281.

1 Introduction

Biogas is a renewable energy source and is a blend of different gases generated by the bacterial digestion of organic matter under anaerobic conditions. Biogas can be generated from substrates such as agricultural wastes, livestock manure, agricultural crop residues, the organic fraction of municipal waste, wastewater, and kitchen leftovers (Samer, 2015a, 2015b; Samer et al., 2019). Biogas consists predominantly of CH_4 and CO_2 as well as small amounts of H_2S, H_2O and a few trace gases such as NH_3, H_2 and N_2. Methane is combusted in the existence of O_2. This energetic content permits biogas to be utilized as a fuel; it can be used for heating and cooking. Also, it can be utilized in internal combustion engines to transform the biogas energetic content into heat and electric energy (Samer, 2012). Biogas technology is a robust method to recycle waste to produce gas fuel (biogas) and high value biofertilizer (Samer, 2010). Anaerobic digestion (AD)

Received date: 2022-02-21 **Accepted date:** 2023-07-13

*** Corresponding author: Mohamed Samer, Professor and Department Head,** Department of Agricultural Engineering, Faculty of Agriculture, Cairo University, 12613 Giza, Egypt. Email: msamer@agr.cu.edu.eg. Tel: +20-(0)2-35738929.

is an efficient emissions abatement technique to decrease the negative environmental effects of organic wastes. Compared to other methods such as composting, anaerobic digestion seizes substantial benefits such as generating energy, recycling organic wastes efficiently, and producing biofertilizer (Samer, 2015a, 2015b; Ioannou-Ttofa et al., 2021).

Recent advancements in the field of biogas focus on the implementation of new technologies such as: nanotechnology (Attia et al., 2018, 2021; Abdelsalam and Samer, 2019; Samer and Abdelsalam et al., 2021), laser radiation (Abdelsalam and Samer et al., 2019; Abdelsalam et al., 2021), and conducting life cycle analysis (LCA) and environmental impact assessment (EIA) using special LCA and EIA software (Abdelsalam and Hijazi et al., 2019; Hijazi et al., 2020a, 2020b; Samer and Hijazi et al., 2021), where the application of these novel technologies requires tremendous calculations which must be conducted using a novel software application that can be easily installed on cell phones.

A software system is an intelligent program that implements know-how and inference processes to solve problems that are complicated enough to necessitate considerable experience for their solution. These software programs handle symbolic descriptions of facts and heuristics to imitate the reasoning processes of the specialists. The essential task of the knowledge engineer is to seize the heuristics or patterns of thought employed by the specialists in the operation of complex problem-solving assignments and denote them in the form of spark maps or flowcharts, i.e., decision trees (Broner et al., 1990; Geer et al., 1994; Samer et al., 2011, 2022a, 2022b, 2023). The assignments achieved by software applications are numerous; the practical categories for software programs are prediction, monitoring, interpretation, diagnosis, repair, instruction, debugging, control, design, and planning (Giarratano and Riley, 2005; Samer, 2010; Samer et al., 2012). The integration of mathematical models and software systems are known as hybrid systems. The benefits of hybrid systems are that models provide quantitative and qualitative information for the software, which in turn computes absent variables for the simulation models (Geer et al., 1994; Samer et al., 2013). The conventional form of a software system is a program with a set of rules or equations that scrutinize data or information provided by the user, regarding a particular problem (Yoo, 1989; Giarratano and Riley, 2005; Samer et al., 2019).

The purpose of this research was to create a tool to aid engineers and specialists in performing specific computations by providing an application which can be installed on cell phones to save time and effort. To be precise, the software aims at sizing the anaerobic digesters and computing the energy production and biogas and methane yields.

2 Materials and methods

2.1 Knowledge acquisition

The simulation models were created through employing the parameters, variables, and constant values of the biogas units and plants available in the references (Samer, 2010, 2012; Samer et al., 2019; El Mashad and Zhang, 2020). Moreover, communications were established with the specialists in the following Egyptian institutions to mimic their expertise thought and using it in creating the structured induction of the software system:

Ministry of Environment and Egyptian Environmental Affairs Agency

Ministry of Agriculture and Land Reclamation

Agricultural Research Center: Soil, Water & Environment Research Institute

New and Renewable Energy Authority

Corporation of Bioenergy for Sustainable Rural Development

Farms having biogas units

After acquiring large amounts of data and information, a software application was created to support users and specialists in computing the parameters of biogas production, where this software application can be installed on cell phones. The software application is designed to size anaerobic digesters and compute energy production and biogas and methane yields. Consequently, the software system is an intelligent cell phone application that uses know-how and inference processes to solve problems that are challenging enough to need considerable expertise for their solution. This software application employs symbolic descriptions of facts and heuristics to imitate the reasoning processes of a specialist. The integration of mathematical models and software applications are known as hybrid systems. The advantages of hybrid systems are that simulations deliver quantitative and qualitative information for the software, which in turn provides lacking variables for the simulation models.

2.2 Data acquisition

The data used to configure the cell phone application was acquired from the abovementioned institutions. Tables 1 and 2 show the data acquired and used to validate and evaluate the developed software application. The highlighted columns in gray are the output data i.e., calculated data. The other not highlighted columns represent the input data.

Table 1 The working parameters produced from different biogas units

Biogas Production Unit	V_w (m^3)	V_{df} (m^3 day^{-1})	HRT (day)	V_t (m^3)	V_h (m^3)	ϕ_{om} (kg VS day^{-1})	Q (kg day^{-1})	T_{sc} (%)	V_{sc} (% of T_{sc})	B_{dp} (m^3 day^{-1})	B_y (m^3 kg^{-1} VS)	M_{dp} (m^3 day^{-1})	M_c (%)
1	3740	93.5		4114	374	7479.64	4.278			2154.2	0.288	1400.2	0.65
2	3964	99.1		4360	396.4	7712.17	4.411			2244.2	0.291	1548.5	0.69
3	3596	89.9		3955.6	359.6	7918.48	4.529			2272.6	0.287	1386.3	0.61
4	3692	92.3	40	4061.2	369.2	8353.83	4.778	21.66	80.72	2464.4	0.295	1626.5	0.66
5	3896	97.4		4285.6	389.6	8600.36	4.919			2408.1	0.280	1493.0	0.62
6	3672	91.8		4039.2	367.2	7014.56	4.012			1999.2	0.285	1379.4	0.69
7	3848	96.2		4232.8	384.8	7540.83	4.313			2209.5	0.293	1480.3	0.67

Note: volume of digester (Vw), volumetric feed to the digester (Vdf), hydraulic retention time (HRT), total volume of a digester (Vt), head space volume (Vh), amount of organic matter to be treated per day (ϕ_{om}), amount of feedstock to be treated (*Q*), total solids contents wet basis (T_{sc}), volatile solids contents (V_{sc}), daily biogas production (B_{dp}), biogas yield production (B_y), daily methane production (M_{dp}), methane content in the biogas (M_c)

Table 2 Parameters produced from different biogas production units

Biogas Production Unit*	E_{dp} (MJ day^{-1})	C_{vb} (MJ m^{-3})	C_{vm} (MJ m^{-3})	a	b	c	d	M_y (%)	S (kg m^{-3})	S_0 (kg m^{-3})	S_{deg} (kg)	M_p (m^3)
1	49545.6										2116.84	1222.84
2	51617.6										2243.62	1296.07
3	52269.9										2035.34	1175.75
4	56680.8	23	35.385	3.7	6.4	1.8	0.2	57.8	4.434	5	2089.67	1207.14
5	55386.3										2205.14	1273.84
6	45980.5										2078.35	1200.60
7	50817.6										2177.97	1258.15

Note: * Data shown in Table 2 are not related to Table 1 i.e., they are for different biogas units

The daily energy production (Edp), calorific value of biogas (Cvb), calorific value of methane (Cvm), methane content in the biogas (My), concentration of the biodegradable organic matter (expressed as VS, COD, or BOD) in the digester after a period of digestion (S), initial concentration of the biodegradable organic matter (expressed as VS, COD, or BOD) in the digester (S0), degraded organic matter in the digester (Sdeg), working volume of digester i.e., volume of liquid inside the digester (Vw) from Table1, amount of methane produced (Mp), number of atoms of carbon, hydrogen, oxygen, and nitrogen, respectively (a, b, c, and d), methane yield (My)

2.3 Programming

MIT App Inventor was used to develop a software program by integrating the flowchart and the mathematical model and making the user interface. The programmed software comprised of a total of 5 programming nodes (Tables 3-7) configured in 7 codes (Figures 1-7). Table 3- 7 show the programming syntax of the main form unit, model selection, add new, load data, compute, export and import data, return to main screen, and exit. On the other hand, Table 8 shows the tools which were used in programming the application.

Table 3 Main screen


```
#|
$JSON
{"authURL":[""],"YaVersion":"213","Source":"Form","Properties":{"$Name":"Screen1","$Type":"Form","$Version":"30","AboutScreen":"","AccentColor":"&HFFFFFFFF","AlignHorizontal":"3","AlignVertical":"2","AppName":"Biogas App","CloseScreenAnimation":"fade","Icon":"logo1.png","OpenScreenAnimation":"fade","Scrollable":"True","Title":"Main","TitleVisible":"False","Uuid":"0","$Components":[{"$Name":"HorizontalArrangement2","$Type":"HorizontalArrangement","$Version":"4","AlignHorizontal":"3","AlignVertical":"2","BackgroundColor":"&HFFFFFFFF","Uuid":"1580888997","$Components":[{"$Name":"Label1","$Type":"Label","$Version":"5","FontSize":"40","Width":"-2","Text":"BiogasApp","TextAlignment":"1","Uuid":"-482072972"}]},{"$Name":"VerticalArrangement5","$Type":"VerticalArrangement","$Version":"4","Uuid":"-1359124495"},{"$Name":"HorizontalArrangement3","$Type":"HorizontalArrangement","$Version":"4","Uuid":"887736405","$Components":[{"$Name":"HorizontalArrangement1","$Type":"HorizontalArrangement","$Version":"4","AlignHorizontal":"3","Height":"200","Width":"200","Image":"logo1.png","Uuid":"213772355"}]},{"$Name":"VerticalArrangement1","$Type":"VerticalArrangement","$Version":"4","AlignHorizontal":"3","BackgroundColor":"&HFFFFFFFF","Height":"-2","Width":"-2","Uuid":"-443075726","$Components":[{"$Name":"VerticalArrangement4","$Type":"VerticalArrangement","$Version":"4","Height":"50","Width":"200","Uuid":"1348544906"},{"$Name":"Button1","$Type":"Button","$Version":"7","BackgroundColor":"&HFFBB9457","FontBold":"True","FontSize":"14","Height":"60","Width":"300","Shape":"1","Text":"Sizing Anaerobic Digesters","TextColor":"&HFFFFFFFF","Uuid":"80894688"},{"$Name":"VerticalArrangement2","$Type":"VerticalArrangement","$Version":"4","Height":"20","Uuid":"1082401597"},{"$Name":"Button2","$Type":"Button","$Version":"7","BackgroundColor":"&HFF6F1D1B","FontBold":"True","FontSize":"14","Height":"60","Width":"300","Shape":"1","Text":"Estimation of Energy Production from a Substrate","TextColor":"&HFFFFFFFF","Uuid":"-660827124"},{"$Name":"VerticalArrangement3","$Type":"VerticalArrangement","$Version":"4","Height":"20","Uuid":"137010617"},{"$Name":"Button3","$Type":"Button","$Version":"7","BackgroundColor":"&HFF4472C4","FontBold":"True","FontSize":"14","Height":"60","Width":"300","Shape":"1","Text":"Estimation of Biogas and MethaneYields","TextColor":"&HFFFFFFFF","Uuid":"-1263853689"},{"$Name":"VerticalArrangement6","$Type":"VerticalArrangement","$Version":"4","Height":"20","Uuid":"-2112569051"},{"$Name":"Exit","$Type":"Button","$Version":"7","BackgroundColor":"&HFF888888","FontBold":"True","FontSize":"14","Height":"60","Width":"300","Shape":"1","Text":"Exit","TextColor":"&HFFFFFFFF","Uuid":"-1037808840"}]},{"$Name":"Notifier1","$Type":"Notifier","$Version":"6","Uuid":"1337081141"},{"$Name":"TinyDB1","$Type":"TinyDB","$Version":"2","Uuid":"1554500291"}]}}
|#
```


Table 4 Sizing anaerobic digesters


```
#|
$JSON
{"authURL":[""],"YaVersion":"213","Source":"Form","Properties":{"$Name":"Sizing_Anaerobic_Digesters","$Type":"Form","$Version":"30","AccentColor":"&HFFFFFFFF","AlignHorizontal":"3","AlignVertical":"2","AppName":"Biogas_Calculator","BackgroundColor":"&HFFCCCCCC","OpenScreenAnimation":"fade","Scrollable":"True","Title":"Sizing Anaerobic Digesters","TitleVisible":"False","Uuid":"0","$Components":[{"$Name":"VerticalScrollArrangement1","$Type":"VerticalScrollArrangement","$Version":"2","AlignHorizontal":"3","BackgroundColor":"&HFFCCCCCC","Width":"-2","Uuid":"-768291979","$Components":[{"$Name":"Label1","$Type":"Label","$Version":"5","FontBold":"True","FontSize":"14","Height":"-2","Width":"-2","Text":"Sizing Anaerobic Digesters","TextAlignment":"1","TextColor":"&HFF007800","Uuid":"1126270131"}]},{"$Name":"VerticalScrollArrangement5","$Type":"VerticalScrollArrangement","$Version":"2","AlignHorizontal":"3","BackgroundColor":"&HFFCCCCCC","Width":"-2","Uuid":"-562637388","$Components":[{"$Name":"Label2","$Type":"Label","$Version":"5","FontSize":"30","Height":"-2","Width":"-2","Text":"Inputs","TextAlignment":"1","Uuid":"-1703018525"}]},{"$Name":"VerticalScrollArrangement2","$Type":"VerticalScrollArrangement","$Version":"2","AlignHorizontal":"3","Width":"-2","Uuid":"1441641175","$Components":[{"$Name":"Image1","$Type":"Image","$Version":"6","Height":"-2","Picture":"in1.png","ScalePictureToFit":"True","Uuid":"354142762"},{"$Name":"B11","$Type":"TextBox","$Version":"6","FontSize":"25","NumbersOnly":"True","TextAlignment":"1","TextColor":"&HFF008100","Uuid":"304585994"},{"$Name":"Image2","$Type":"Image","$Version":"6","Height":"-2","Picture":"in2.png","ScalePictureToFit":"True","Uuid":"1088380855"},{"$Name":"L11","$Type":"TextBox","$Version":"6","FontSize":"25","NumbersOnly":"True","TextAlignment":"1","TextColor":"&HFF007000","Uuid":"-596819806"}]},{"$Name":"VerticalScrollArrangement4","$Type":"VerticalScrollArrangement","$Version":"2","AlignHorizontal":"3","Width":"-2","Uuid":"-2010901202","$Components":[{"$Name":"Label3","$Type":"Label","$Version":"5","FontSize":"30","Text":"Outputs","TextAlignment":"1","Uuid":"449055578"}]},{"$Name":"VerticalScrollArrangement3","$Type":"VerticalScrollArrangement","$Version":"2","AlignHorizontal":"3","Width":"-2","Uuid":"-1220651161","$Components":[{"$Name":"Image3","$Type":"Image","$Version":"6","Height":"-2","Picture":"out1.png","ScalePictureToFit":"True","Uuid":"1062095329"},{"$Name":"G16","$Type":"TextBox","$Version":"6","FontSize":"25","NumbersOnly":"True","ReadOnly":"True","Text":"0","TextAlignment":"1","TextColor":"&HFFFF0000","Uuid":"1632135851"},{"$Name":"Image4","$Type":"Image","$Version":"6","Height":"-2","Picture":"out2.png","ScalePictureToFit":"True","Uuid":"1550895389"},{"$Name":"B24","$Type":"TextBox","$Version":"6","FontSize":"25","NumbersOnly":"True","ReadOnly":"True","Text":"0","TextAlignment":"1","TextColor":"&HFFFF0000","Uuid":"1524768862"},{"$Name":"Image5","$Type":"Image","$Version":"6","Height":"-2","Picture":"out3.png","ScalePictureToFit":"True","Uuid":"49794908"},{"$Name":"G24","$Type":"TextBox","$Version":"6","FontSize":"25","NumbersOnly":"True","ReadOnly":"True","Text":"0","TextAlignment":"1","TextColor":"&HFFFF0000","Uuid":"1639020321"}]},{"$Name":"tools1","$Type":"HorizontalScrollArrangement","$Version":"2","AlignVertical":"2","BackgroundColor":"&HFFCCCCCC","Uuid":"747964979","$Components":[{"$Name":"VerticalArrangement1","$Type":"VerticalArrangement","$Version":"4","Ali
```

gnHorizontal":"3","AlignVertical":"2","Uuid":"-693935273","$Components":[{"$Name":"calculate","$Type":"Button","$Version":"7","FontSize":"12","Height":"-2","Width":"80","Text":"Compute","Uuid":"2073287605"}]},{"$Name":"VerticalArrangement4","$Type":"VerticalArrangement","$Version":"4","AlignHorizontal":"3","AlignVertical":"2","Uuid":"-115091280","$Components":[{"$Name":"add","$Type":"Button","$Version":"7","FontSize":"12","Height":"-2","Width":"80","Text":"Add new","Uuid":"1413525235"}]},{"$Name":"VerticalArrangement2","$Type":"VerticalArrangement","$Version":"4","AlignHorizontal":"3","AlignVertical":"2","Uuid":"2002583882","$Components":[{"$Name":"save","$Type":"Button","$Version":"7","Height":"-2","Width":"80","Text":"Save","Uuid":"2014293142"}]},{"$Name":"VerticalArrangement3","$Type":"VerticalArrangement","$Version":"4","AlignHorizontal":"3","AlignVertical":"2","Uuid":"74067772","$Components":[{"$Name":"Import","$Type":"Button","$Version":"7","FontSize":"14","Height":"-2","Width":"80","Text":"Import","Uuid":"787974460"}]}]},{"$Name":"tools2","$Type":"VerticalArrangement","$Version":"4","AlignHorizontal":"3","AlignVertical":"2","Width":"-2","Uuid":"1247407074","$Components":[{"$Name":"home","$Type":"Button","$Version":"7","Height":"-2","Width":"320","Text":"Home","Uuid":"1469922395"}]},{"$Name":"HorizontalArrangement1","$Type":"HorizontalArrangement","$Version":"4","AlignHorizontal":"3","AlignVertical":"2","Uuid":"824297173","Visible":"False","$Components":[{"$Name":"Label4","$Type":"Label","$Version":"5","FontBold":"True","Text":"File Name: ","Uuid":"-575963350"},{"$Name":"TextBox1","$Type":"TextBox","$Version":"6","Uuid":"-114085945"},{"$Name":"Button1","$Type":"Button","$Version":"7","TextAlignment":"2","Uuid":"1853120794"}]},{"$Name":"Notifier1","$Type":"Notifier","$Version":"6","Uuid":"-1589276884"},{"$Name":"File1","$Type":"File","$Version":"4","Uuid":"74547967"},{"$Name":"TaifunFile1","$Type":"TaifunFile","$Version":"13","Uuid":"-1154820498"},{"$Name":"Sharing1","$Type":"Sharing","$Version":"1","Uuid":"-1631015812"},{"$Name":"TaifunTools1","$Type":"TaifunTools","$Version":"21","Uuid":"1077492377"},{"$Name":"TinyDB1","$Type":"TinyDB","$Version":"2","Uuid":"-2072129096"}]}}
|#

Table 5 Estimation of energy production from a substrate

#|
$JSON30
{"authURL":[""],"YaVersion":"213","Source":"Form","Properties":{"$Name":"Estimation_of_Energy","$Type":"Form","$Version":"","AccentColor":"&HFFFFFFFF","AlignHorizontal":"3","AlignVertical":"2","AppName":"Biogas_Calculator","BackgroundColor":"&HFFCCCCCC","CloseScreenAnimation":"fade","OpenScreenAnimation":"fade","Scrollable":"True","Title":"Estimation of Energy","TitleVisible":"False","Uuid":"0","$Components":[{"$Name":"VerticalScrollArrangement1","$Type":"VerticalScrollArrangement","$Version":"2","AlignHorizontal":"3","BackgroundColor":"&HFFCCCCCC","Width":"-2","Uuid":"1369912145","$Components":[{"$Name":"Label1","$Type":"Label","$Version":"5","FontBold":"True","FontSize":"14","Height":"-2","Width":"-2","Text":"Estimation of Energy Production from a Substrate","TextAlignment":"1","TextColor":"&HFF007800","Uuid":"336323576"}]},{"$Name":"VerticalScrollArrangement2","$Type":"VerticalScrollArrangement","$Version":"2","AlignHorizontal":"3","BackgroundColor":"&HFFCCCCCC","Width":"-2","Uuid":"-1542594490","$Components":[{"$Name":"Label2","$Type":"Label","$Version":"5","FontSize":"30","Height":"-2","Width":"-2","Text":"Inputs","TextAlignment":"1","Uuid":"1072069605"}]},{"$Name":"VerticalScrollArrangement3","$Type":"VerticalScrollArrangement","$Version":"2","AlignHorizontal":"3","Width":"-2","Uuid":"-630030982","$Components":[{"$Name":"Image1","$Type":"Image","$Version":"6","Height":"-2","Picture":"in2-1.png","ScalePictureToFit":"True","Uuid":"-1709025986"},{"$Name":"C4","$Type":"TextBox","$Version":"6","FontSize":"25","NumbersOnly":"True","TextAlignment":"1","TextColor":"&HFF008100","Uuid":"-15388746"},{"$Name":"Image2","$Type":"Image","$Version":"6","Height":"-2","Picture":"in2-2.png","ScalePictureToFit":"True","Uuid":"1138486093"},{"$Name":"G4","$Type":"TextBox","$Version":"6","FontSize":"25","NumbersOnly":"True","TextAlignment":"1","TextColor":"&HFF008100","Uuid":"2025953275"},{"$Name":"Image6","$Type":"Image","$Version":"6","Height":"-2","Picture":"in2-3.png","ScalePictureToFit":"True","Uuid":"-335327292"},{"$Name":"K4","$Type":"TextBox","$Version":"6","FontSize":"25","NumbersOnly":"True","TextAlignment":"1","TextColor":"&HFF008100","Uuid":"1444041073"},{"$Name":"Image7","$Type":"Image","$Version":"6","Height":"-2","Picture":"in2-4.png","ScalePictureToFit":"True","Uuid":"765397534"},{"$Name":"C16","$Type":"TextBox","$Version":"6","FontSize":"25","NumbersOnly":"True","TextAlignment":"1","TextColor":"&HFF008100","Uuid":"1496960956"},{"$Name":"Image8","$Type":"Image","$Version":"6","Height":"-2","Picture":"in2-5.png","ScalePictureToFit":"True","Uuid":"-1035744002"},{"$Name":"O16","$Type":"TextBox","$Version":"6","FontSize":"25","NumbersOnly":"True","TextAlignment":"1","TextColor":"&HFF007000","Uuid":"1637222800"},{"$Name":"Image11","$Type":"Image","$Version":"6","Height":"-2","Picture":"in2-6.png","ScalePictureToFit":"True","Uuid":"828598547"},{"$Name":"C22","$Type":"TextBox","$Version":"6","FontSize":"25","NumbersOnly":"True","TextAlignment":"1","TextColor":"&HFF007000","Uuid":"1986488414"},{"$Name":"Image12","$Type":"Image","$Version":"6","Height":"-2","Picture":"in2-7.png","ScalePictureToFit":"True","Uuid":"-1531890453"},{"$Name":"O22","$Type":"TextBox","$Version":"6","FontSize":"25","NumbersOnly":"True","TextAlignment":"1","TextColor":"&HFF007000","Uuid":"-353330757"}]},{"$Name":"VerticalScrollArrangement4","$Type":"VerticalScrollArrangement","$Version":"2","AlignHorizontal":"3","Width":"-2","Uuid":"-191675322","$Components":[{"$Name":"Label3","$Type":"Label","$Version":"5","FontSize":"30","Text":"Outputs","TextAlignment":"1","Uuid":"-604394158"}]},{"$Name":"VerticalScrollArrangement5","$Type":"VerticalScrollArrangement","$Version":"2","AlignHorizontal":"3","Width":"-2","Uuid":"1031141646","$Components":[{"$Name":"Image3","$Type":"Image","$Version":"6","Height":"-2","Picture":"out2-1.png","RotationAngle":"0","ScalePictureToFit":"True","Uuid":"-1373306530"},{"$Name":"G10","$Type":"TextBox","$Version":"6","FontSize":"25","NumbersOnly":"True","ReadOnly":"True","Text":"0","TextAlignment":"1","TextColor":"&HFFFF0000","Uuid":"-1240207468"},{"$Name":"Image9","$Type":"Image","$Version":"6","Height

":"-2","Picture":"out2-
2.png","RotationAngle":"0","ScalePictureToFit":"True","Uuid":"214421909"
},{"$Name":"G16","$Type":"TextBox","$Version":"6","FontSize":"25","Nu
mbersOnly":"True","ReadOnly":"True","Text":"0","TextAlignment":"1","Te
xtColor":"&HFFFF0000","Uuid":"1838018432"},{"$Name":"Image10","$Ty
pe":"Image","$Version":"6","Height":"-2","Picture":"out2-
3.png","RotationAngle":"0","ScalePictureToFit":"True","Uuid":"-
1371673177"},{"$Name":"K16","$Type":"TextBox","$Version":"6","FontSi
ze":"25","NumbersOnly":"True","ReadOnly":"True","Text":"0","TextAlignm
ent":"1","TextColor":"&HFFFF0000","Uuid":"1758087142"},{"$Name":"Im
age4","$Type":"Image","$Version":"6","Height":"-2","Picture":"out2-
4.png","ScalePictureToFit":"True","Uuid":"-
564654246"},{"$Name":"G22","$Type":"TextBox","$Version":"6","FontSiz
e":"25","NumbersOnly":"True","ReadOnly":"True","Text":"0","TextAlignme
nt":"1","TextColor":"&HFFFF0000","Uuid":"109194239"},{"$Name":"Imag
e5","$Type":"Image","$Version":"6","Height":"-2","Picture":"out2-
5.png","ScalePictureToFit":"True","Uuid":"-
72250774"},{"$Name":"K22","$Type":"TextBox","$Version":"6","FontSize"
:"25","NumbersOnly":"True","ReadOnly":"True","Text":"0","TextAlignment
":"1","TextColor":"&HFFFF0000","Uuid":"1934035482"}]},{"$Name":"tool
s1","$Type":"HorizontalScrollArrangement","$Version":"2","AlignVertical":
"2","BackgroundColor":"&HFFCCCCCC","Uuid":"-
1397507494","$Components":[{"$Name":"VerticalArrangement1","$Type":"
VerticalArrangement","$Version":"4","AlignHorizontal":"3","AlignVertical":
"2","Uuid":"-
996712454","$Components":[{"$Name":"calculate","$Type":"Button","$Ver
sion":"7","FontSize":"12","Height":"-
2","Width":"80","Text":"Compute","Uuid":"1937444618"}]},{"$Name":"Ver
ticalArrangement4","$Type":"VerticalArrangement","$Version":"4","AlignH
orizontal":"3","AlignVertical":"2","Uuid":"1554952030","$Components":[{"
$Name":"add","$Type":"Button","$Version":"7","FontSize":"12","Height":"-
2","Width":"80","Text":"Add new","Uuid":"-
345895824"}]},{"$Name":"VerticalArrangement2","$Type":"VerticalArrang
ement","$Version":"4","AlignHorizontal":"3","AlignVertical":"2","Uuid":"97
6865953","$Components":[{"$Name":"save","$Type":"Button","$Version":"
7","Height":"-
2","Width":"80","Text":"Save","Uuid":"106173916"}]},{"$Name":"Vertical
Arrangement3","$Type":"VerticalArrangement","$Version":"4","AlignHoriz
ontal":"3","AlignVertical":"2","Uuid":"-
1480120464","$Components":[{"$Name":"Import","$Type":"Button","$Vers
ion":"7","FontSize":"14","Height":"-
2","Width":"80","Text":"Import","Uuid":"298672204"}]}]},{"$Name":"tools
2","$Type":"VerticalArrangement","$Version":"4","AlignHorizontal":"3","Al
ignVertical":"2","Width":"-2","Uuid":"-
1873085005","$Components":[{"$Name":"home","$Type":"Button","$Versi
on":"7","Height":"-
2","Width":"320","Text":"Home","Uuid":"435880372"}]},{"$Name":"Horizo
ntalArrangement1","$Type":"HorizontalArrangement","$Version":"4","Align
Horizontal":"3","AlignVertical":"2","Uuid":"-
1028405796","Visible":"False","$Components":[{"$Name":"Label4","$Type
":"Label","$Version":"5","FontBold":"True","Text":"File Name: ","Uuid":"-
829728256"},{"$Name":"TextBox1","$Type":"TextBox","$Version":"6","Uu
id":"2102676958"},{"$Name":"Button1","$Type":"Button","$Version":"7","
TextAlignment":"2","Uuid":"790938483"}]},{"$Name":"Notifier1","$Type":
"Notifier","$Version":"6","Uuid":"579408746"},{"$Name":"File1","$Type":"
File","$Version":"4","Uuid":"918827381"},{"$Name":"TaifunFile1","$Type"
:"TaifunFile","$Version":"13","Uuid":"-
20373439"},{"$Name":"Sharing1","$Type":"Sharing","$Version":"1","Uuid"
:"-
1497383145"},{"$Name":"TaifunTools1","$Type":"TaifunTools","$Version"
:"21","Uuid":"1233136920"}]}}
|#

Table 6 Estimation of biogas and methane yields

#|
$JSON
{"authURL":[""],"YaVersion":"213","Source":"Form","Properties":{"$Name
":"Estimation_of_Biogas","$Type":"Form","$Version":"30","AccentColor":"
&HFFFFFFFF","AlignHorizontal":"3","AlignVertical":"2","AppName":"Bio
gas_Calculator","BackgroundColor":"&HFFCCCCCC","CloseScreenAnimati
on":"fade","OpenScreenAnimation":"fade","Scrollable":"True","Title":"Estim
ation of
Energy","TitleVisible":"False","Uuid":"0","$Components":[{"$Name":"Verti
calScrollArrangement1","$Type":"VerticalScrollArrangement","$Version":"2
","AlignHorizontal":"3","BackgroundColor":"&HFFCCCCCC","Width":"-
2","Uuid":"1429391990","$Components":[{"$Name":"Label1","$Type":"Lab
el","$Version":"5","FontBold":"True","FontSize":"14","Height":"-
2","Width":"-2","Text":"Estimation of Biogas and Methane
Yields","TextAlignment":"1","TextColor":"&HFF007800","Uuid":"-
411475144"}]},{"$Name":"VerticalScrollArrangement2","$Type":"VerticalS
crollArrangement","$Version":"2","AlignHorizontal":"3","BackgroundColor"
:"&HFFCCCCCC","Width":"-2","Uuid":"-
1878775036","$Components":[{"$Name":"Label2","$Type":"Label","$Versi
on":"5","FontSize":"30","Height":"-2","Width":"-
2","Text":"Inputs","TextAlignment":"1","Uuid":"1157208143"}]},{"$Name":
"VerticalScrollArrangement3","$Type":"VerticalScrollArrangement","$Versi
on":"2","AlignHorizontal":"3","Width":"-2","Uuid":"-
727469995","$Components":[{"$Name":"Image1","$Type":"Image","$Versi
on":"6","Height":"-2","Picture":"in3-
1.png","ScalePictureToFit":"True","Uuid":"292055409"},{"$Name":"C3","$
Type":"TextBox","$Version":"6","FontSize":"25","NumbersOnly":"True","T
extAlignment":"1","TextColor":"&HFF008100","Uuid":"-
1860351973"},{"$Name":"Image2","$Type":"Image","$Version":"6","Height
":"-2","Picture":"in3-
2.png","ScalePictureToFit":"True","Uuid":"1696980263"},{"$Name":"G3","
$Type":"TextBox","$Version":"6","FontSize":"25","NumbersOnly":"True","
TextAlignment":"1","TextColor":"&HFF008100","Uuid":"1642167167"},{"$
Name":"Image6","$Type":"Image","$Version":"6","Height":"-
2","Picture":"in3-
3.png","ScalePictureToFit":"True","Uuid":"253499239"},{"$Name":"K3","$
Type":"TextBox","$Version":"6","FontSize":"25","NumbersOnly":"True","T
extAlignment":"1","TextColor":"&HFF008100","Uuid":"1784817617"},{"$N
ame":"Image7","$Type":"Image","$Version":"6","Height":"-
2","Picture":"in3-
4.png","ScalePictureToFit":"True","Uuid":"262123162"},{"$Name":"O3","$
Type":"TextBox","$Version":"6","FontSize":"25","NumbersOnly":"True","T
extAlignment":"1","TextColor":"&HFF008100","Uuid":"486240707"},{"$Na
me":"Image8","$Type":"Image","$Version":"6","Height":"-2","Picture":"in3-
5.png","ScalePictureToFit":"True","Uuid":"-
918853049"},{"$Name":"C9","$Type":"TextBox","$Version":"6","FontSize"
:"25","NumbersOnly":"True","TextAlignment":"1","TextColor":"&HFF0070
00","Uuid":"-
852266135"},{"$Name":"Image11","$Type":"Image","$Version":"6","Height
":"-2","Picture":"in3-
6.png","ScalePictureToFit":"True","Uuid":"1718738589"},{"$Name":"C15",

"$Type":"TextBox","$Version":"6","FontSize":"25","NumbersOnly":"True","TextAlignment":"1","TextColor":"&HFF007000","Uuid":"-1217808825"},{"$Name":"Image12","$Type":"Image","$Version":"6","Height":"-2","Picture":"in3-7.png","ScalePictureToFit":"True","Uuid":"607486754"},{"$Name":"C21","$Type":"TextBox","$Version":"6","FontSize":"25","NumbersOnly":"True","TextAlignment":"1","TextColor":"&HFF007000","Uuid":"-2139934738"}]},{"$Name":"VerticalScrollArrangement4","$Type":"VerticalScrollArrangement","$Version":"2","AlignHorizontal":"3","Width":"-2","Uuid":"1187601709","$Components":[{"$Name":"Label3","$Type":"Label","$Version":"5","FontSize":"30","Text":"Outputs","TextAlignment":"1","Uuid":"1021109498"}]},{"$Name":"VerticalScrollArrangement5","$Type":"VerticalScrollArrangement","$Version":"2","AlignHorizontal":"3","Width":"-2","Uuid":"-535421436","$Components":[{"$Name":"Image3","$Type":"Image","$Version":"6","Height":"-2","Picture":"out3-1.png","RotationAngle":"0","ScalePictureToFit":"True","Uuid":"-1614370566"},{"$Name":"I13","$Type":"TextBox","$Version":"6","FontSize":"25","NumbersOnly":"True","ReadOnly":"True","Text":"0","TextAlignment":"1","TextColor":"&HFFFF0000","Uuid":"963199024"},{"$Name":"Image9","$Type":"Image","$Version":"6","Height":"-2","Picture":"out3-2.png","RotationAngle":"0","ScalePictureToFit":"True","Uuid":"-1470813271"},{"$Name":"I19","$Type":"TextBox","$Version":"6","FontSize":"25","NumbersOnly":"True","ReadOnly":"True","Text":"0","TextAlignment":"1","TextColor":"&HFFFF0000","Uuid":"-2030686410"},{"$Name":"Image10","$Type":"Image","$Version":"6","Height":"-2","Picture":"out3-3.png","RotationAngle":"0","ScalePictureToFit":"True","Uuid":"-2067692373"},{"$Name":"O16","$Type":"TextBox","$Version":"6","FontSize":"25","NumbersOnly":"True","ReadOnly":"True","Text":"0","TextAlignment":"1","TextColor":"&HFFFF0000","Uuid":"-382694932"}]}]},{"$Name":"tools1","$Type":"HorizontalScrollArrangement","$Version":"2","AlignVertical":"2","BackgroundColor":"&HFFCCCCCC","Uuid":"101561981","$Components":[{"$Name":"VerticalArrangement1","$Type":"VerticalArrangement","$Version":"4","AlignHorizontal":"3","AlignVertical":"2","Uuid":"658710585","$Components":[{"$Name":"calculate","$Type":"Button","$Version":"7","FontSize":"12","Height":"-2","Width":"80","Text":"Compute","Uuid":"-530594741"}]},{"$Name":"VerticalArrangement4","$Type":"VerticalArrangement","$Version":"4","AlignHorizontal":"3","AlignVertical":"2","Uuid":"1458559931","$Components":[{"$Name":"add","$Type":"Button","$Version":"7","FontSize":"12","Height":"-2","Width":"80","Text":"Add new","Uuid":"549911088"}]},{"$Name":"VerticalArrangement2","$Type":"VerticalArrangement","$Version":"4","AlignHorizontal":"3","AlignVertical":"2","Uuid":"688539908","$Components":[{"$Name":"save","$Type":"Button","$Version":"7","Height":"-2","Width":"80","Text":"Save","Uuid":"-1633435043"}]},{"$Name":"VerticalArrangement3","$Type":"VerticalArrangement","$Version":"4","AlignHorizontal":"3","AlignVertical":"2","Uuid":"1974791840","$Components":[{"$Name":"Import","$Type":"Button","$Version":"7","FontSize":"14","Height":"-2","Width":"80","Text":"Import","Uuid":"-2011070099"}]}]},{"$Name":"tools2","$Type":"VerticalArrangement","$Version":"4","AlignHorizontal":"3","AlignVertical":"2","Width":"-2","Uuid":"1086811867","$Components":[{"$Name":"home","$Type":"Button","$Version":"7","Height":"-2","Width":"320","Text":"Home","Uuid":"21394225"}]},{"$Name":"HorizontalArrangement1","$Type":"HorizontalArrangement","$Version":"4","AlignHorizontal":"3","AlignVertical":"2","Uuid":"-293233053","Visible":"False","$Components":[{"$Name":"Label4","$Type":"Label","$Version":"5","FontBold":"True","Text":"File Name: ","Uuid":"-227789949"},{"$Name":"TextBox1","$Type":"TextBox","$Version":"6","Uuid":"812934583"},{"$Name":"Button1","$Type":"Button","$Version":"7","TextAlignment":"2","Uuid":"2115031981"}]},{"$Name":"Notifier1","$Type":"Notifier","$Version":"6","Uuid":"-267484779"},{"$Name":"File1","$Type":"File","$Version":"4","Uuid":"389362116"},{"$Name":"TaifunFile1","$Type":"TaifunFile","$Version":"13","Uuid":"1810027744"},{"$Name":"Sharing1","$Type":"Sharing","$Version":"1","Uuid":"-94485976"},{"$Name":"TaifunTools1","$Type":"TaifunTools","$Version":"21","Uuid":"-1657055410"},{"$Name":"TinyDB1","$Type":"TinyDB","$Version":"2","Uuid":"-291010174"}]}}
|#

Table 7 Properties of the cell phone application

```
#
#Thu Sep 23 18:00:06 UTC 2021
defaultfilescope=App
showlistsasjson=True
main=appinventor.ai_xcodee.Biogas_App.Screen1
color.accent=&HFFFFFFFF
sizing=Responsive
color.primary.dark=&HFF303F9F
build=../build
actionbar=False
source=../src
useslocation=False
color.primary=&HFF3F51B5
assets=../assets
versionname=1.0
icon=logo1.png
aname=Biogas App
versioncode=1
theme=Classic
name=Biogas_App
```

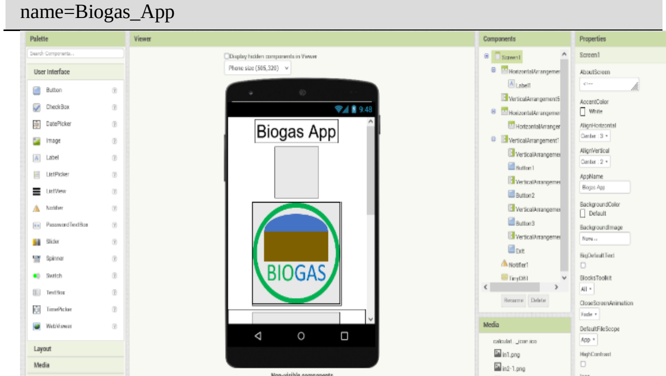

Figure 1 The used codes (Part 1)

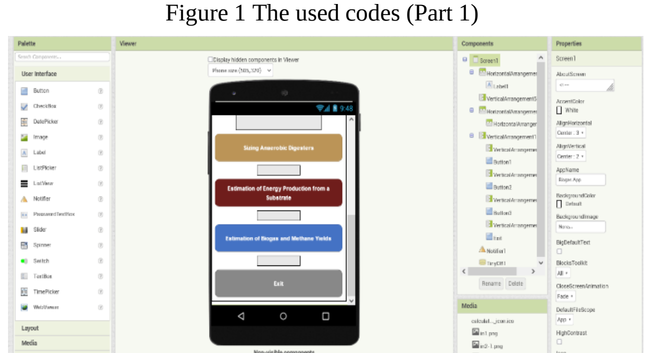

Figure 2 The used codes (Part 2)

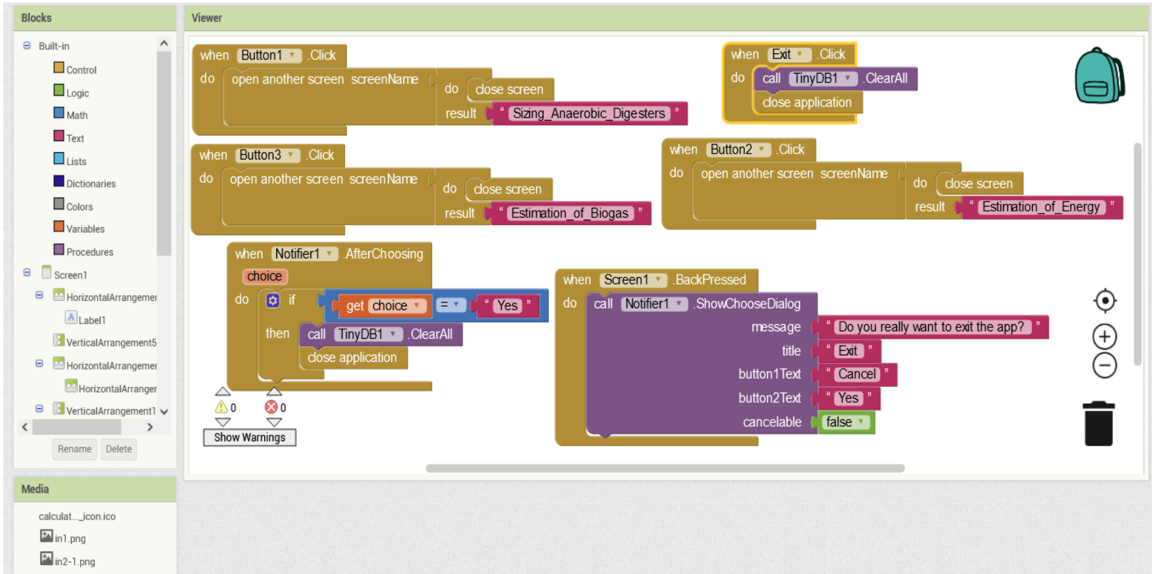

Figure 3 The used codes (Part 3)

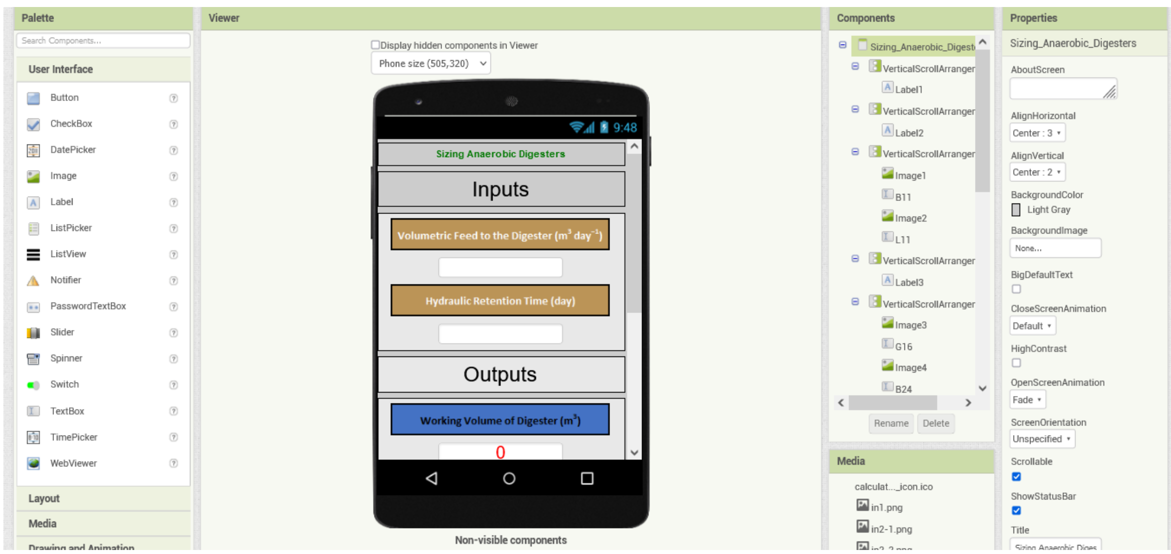

Figure 4 The used codes (Part 4)

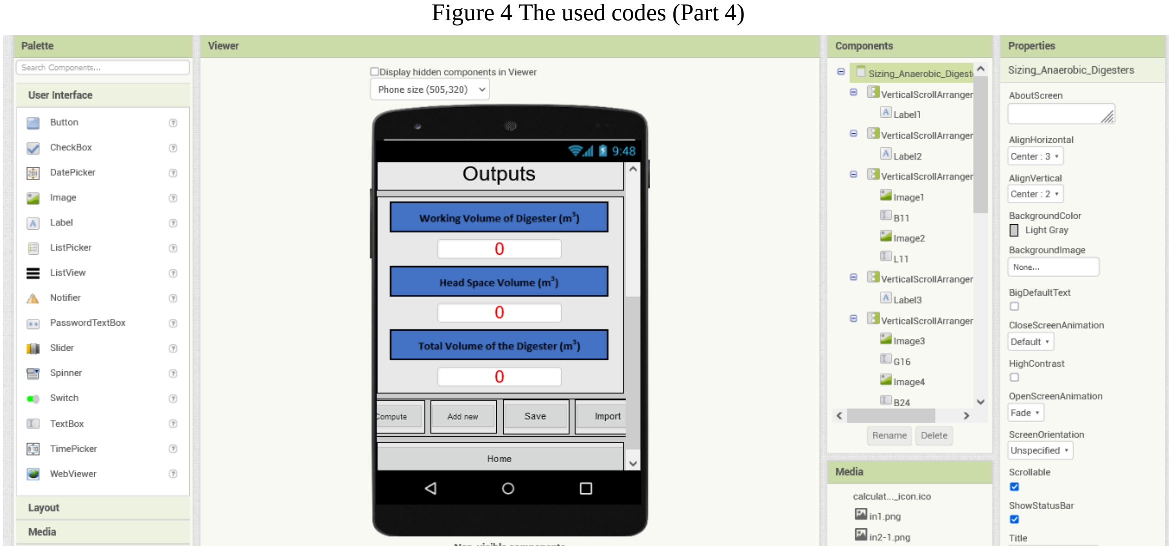

Figure 5 The used codes (Part 5)

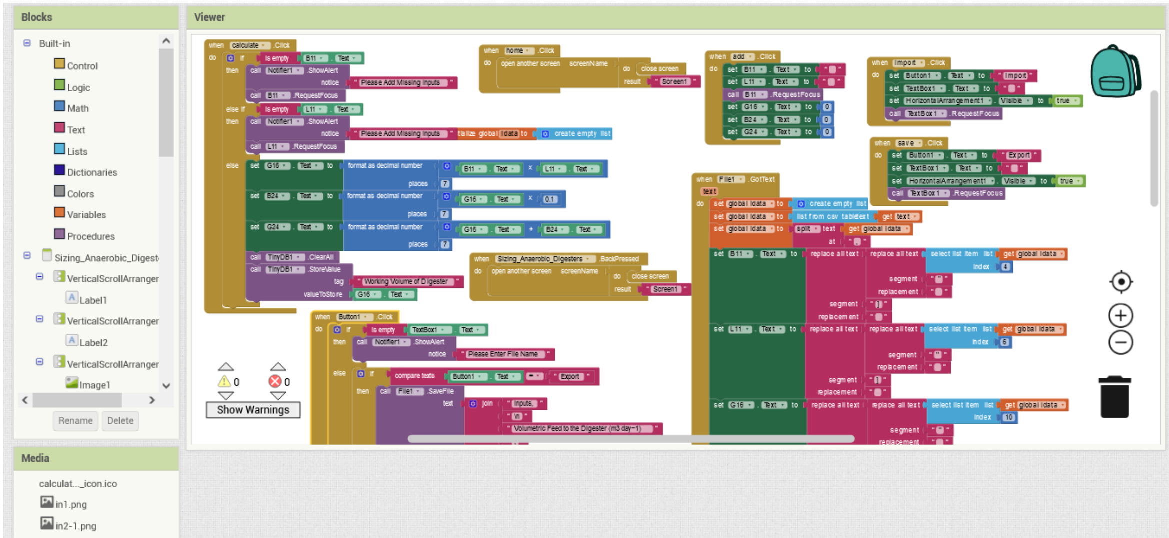

Figure 6 The used codes (Part 6)

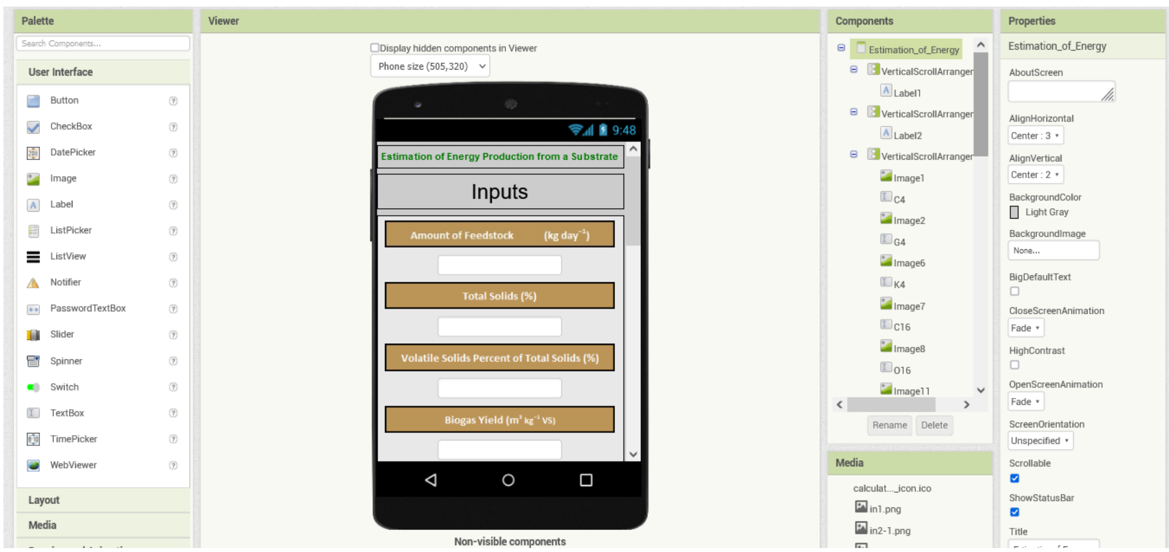

Figure 7 The used codes (Part 7)

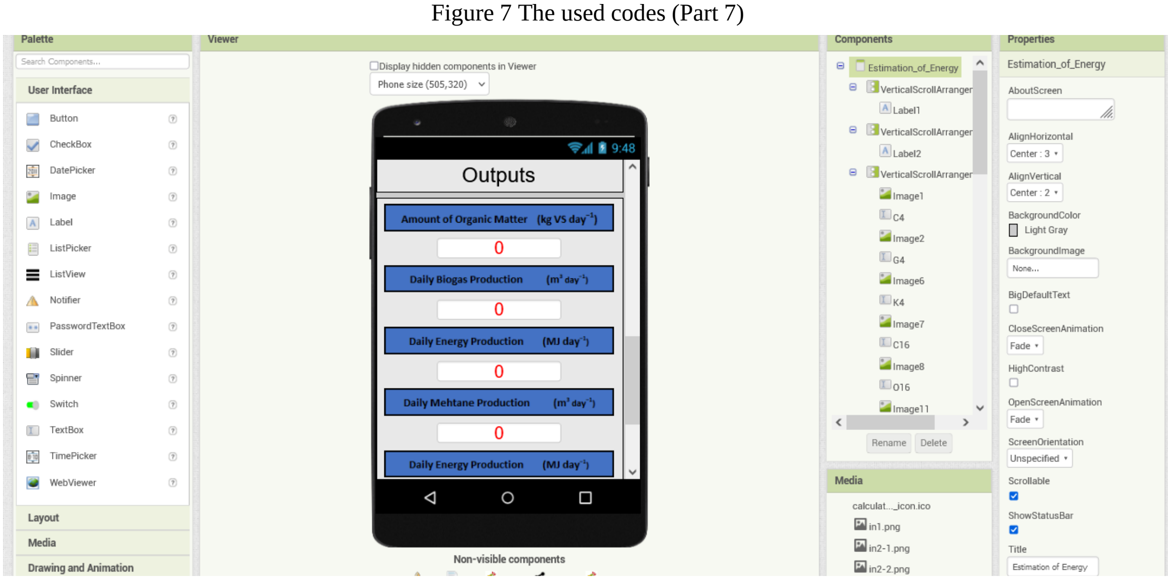

Figure 8 The used codes (Part 8)

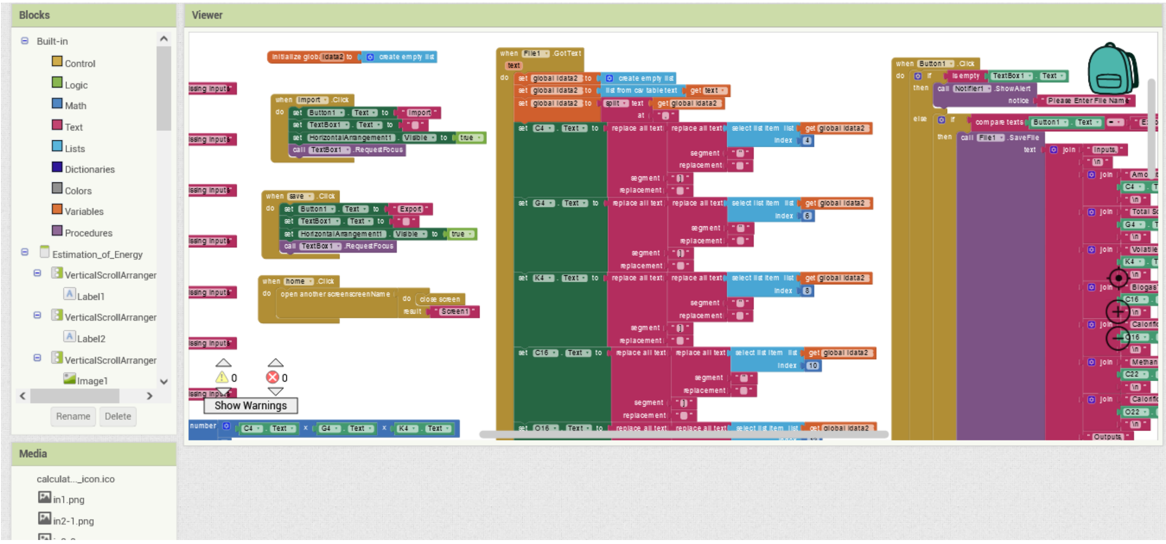

Figure 9 The used codes (Part 9)

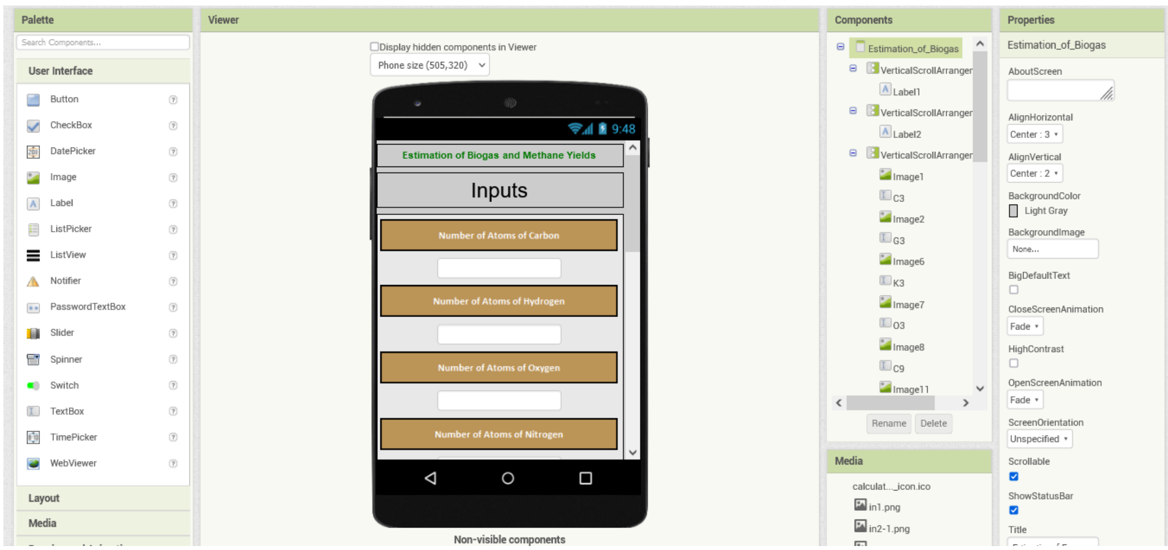

Figure 10 The used codes (Part 10)

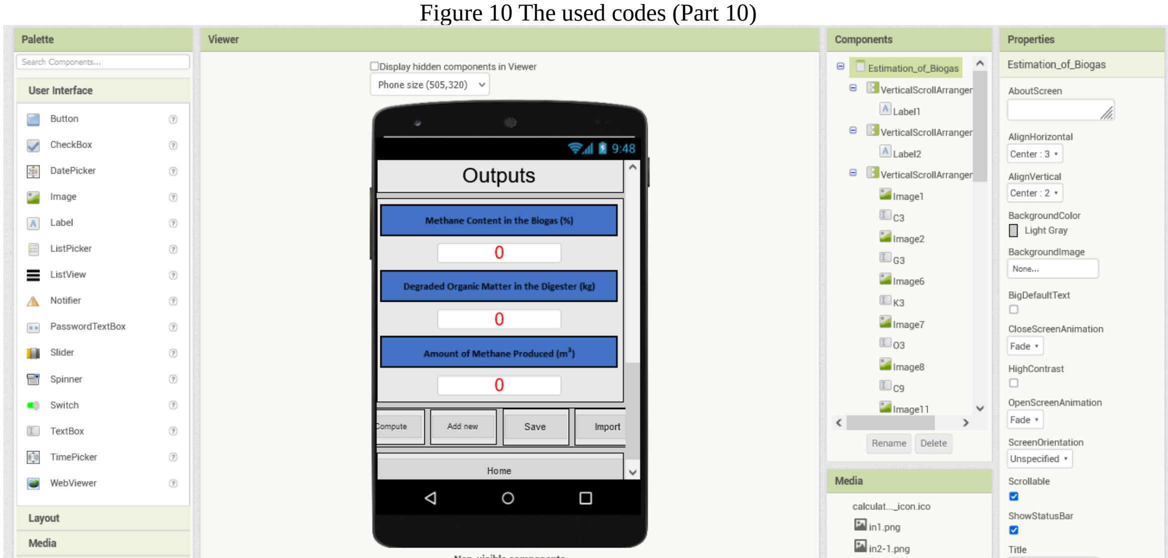

Figure 11 The used codes (Part 11)

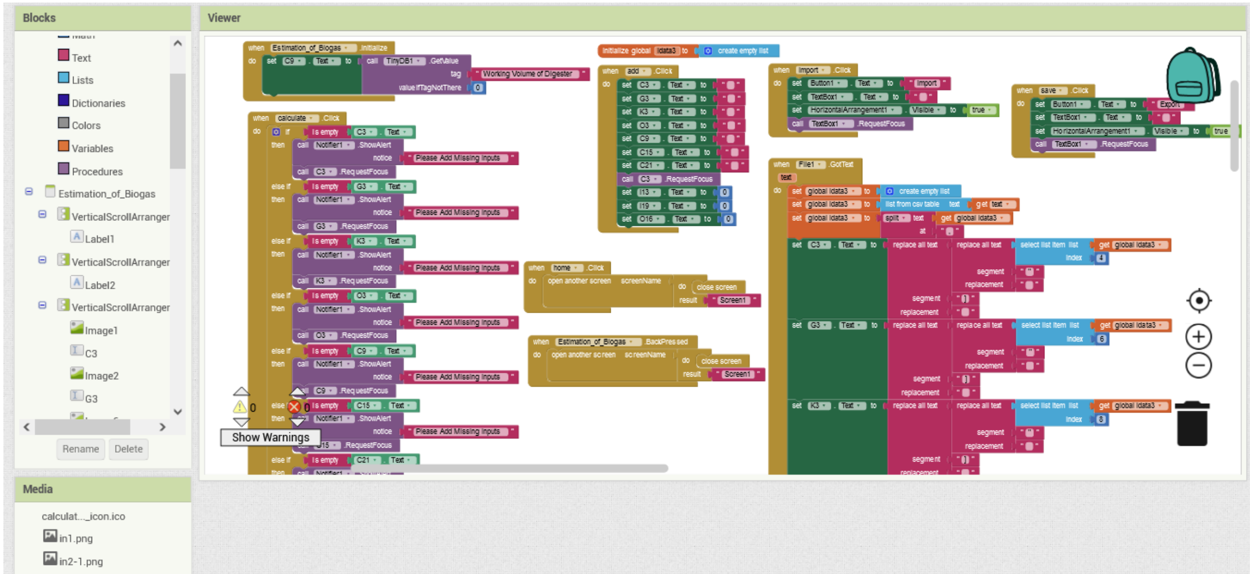

Figure 12 The used codes (Part 12)

Table 8 The tools which were used in programming the application

Tools	Types and Importance
Add New	Adding new set of data
Load Data	Load data from CSV file
Compute	Compute data and get results
Export Data	Export data and save in CVS file for later use
Home	Return to application main screen to select another model

2.4 Mathematical modeling

2.4.1 Sizing anaerobic digesters

The working volume of a digester can be calculated using the hydraulic retention time (HRT) and the volume of waste to be treated per day (El Mashad and Zhang, 2020):

$$V_w = V_{df} \times HRT \qquad (1)$$

Where,

V_w : working volume of digester, m^3

V_{df} : volumetric feed to the digester, m^3 day^{-1}

HRT: hydraulic retention time (day)

The total volume (V_t) of a digester is computed using the working volume (V_w) and head space volume (V_h) as:

$$V_t = V_w + V_h \qquad (2)$$

The head space volume is the gas volume above the liquid that is occasionally utilized for gas storage. The head space volume is typically 10% of the working volume.

2.4.2 Estimation of energy production from a substrate

The produced energy from a digester is quantified by means of the quantity of organic matter that is treated in a specific period (e.g., day), biogas yield, and methane content in the produced biogas. Based on the total solids (TS) and volatile solids (VS) contents of the feedstock, the quantity of organic matter is calculated using the following equation (El Mashad and Zhang, 2020):

$$\phi_{om} = Q \times T_{sc} \times V_{sc} \qquad (3)$$

Where,

ϕ_{om} : amount of organic matter to be treated per day, kg [VS] day^{-1}

Q : amount of feedstock to be treated (kg day^{-1})

T_{sc} : total solids contents, %, wet basis

V_{sc} : volatile solids contents, % of T_{sc}

The daily biogas and methane production is then computed as:

$$B_{dp} = \phi_{om} B_y \qquad (4)$$

$$M_{dp} = B_{dp} M_c \tag{5}$$

Where,

B_{dp} : daily biogas production, $m^3\ day^{-1}$

B_y : biogas yield production, $m^3\ kg^{-1}$ [VS]

M_{dp} : daily methane production, $m^3\ day^{-1}$

M_c : methane content in the biogas, % vol vol^{-1}

The daily energy production from biogas is then computed using Equation 6 or Equation 7 as following:

$$E_{dp} = B_{dp} \times C_{vb} \tag{6}$$

$$E_{dp} = M_{dp} \times C_{vm} \tag{7}$$

Where,

E_{dp} : daily energy production, MJ day^{-1}

C_{vb} : calorific value of biogas, MJ m^{-3}

C_{vm} : calorific value of methane, MJ m^{-3}

2.4.3 Estimation of biogas and methane yields

The volume of the biogas or methane yielded from one gram of the substrate (L g^{-1} VS) is computed using the molar volume of an ideal gas as 22.4 L at the standard temperature and pressure as (El Mashad and Zhang, 2020):

$$M_y = \frac{(\frac{4a+b-2c-3d}{8}) \times 22.4}{12a+b+16c+14d} \tag{8}$$

Where,

M_y: methane content in the biogas, % (mole/mole or v/v)

a, *b*, *c*, and *d* : number of atoms of carbon, hydrogen, oxygen, and nitrogen, respectively

The quantity of degraded organic matter that is transformed into methane, and the amount of methane produced is computed using the following equation:

$$S_{\deg} = V_w (S_0 - S) \tag{9}$$

$$M_p = M_y S_{\deg} \tag{10}$$

Where,

S : concentration of the biodegradable organic matter (expressed as VS, COD, or BOD) in the digester (kg m^{-3}) after a period of digestion (*t*) or Hydraulic Retention Time (HRT)

S_0 : initial concentration of the biodegradable organic matter (expressed as VS, COD, or BOD) in the digester (kg m^{-3})

S_{deg} : degraded organic matter in the digester (kg)

V_w : working volume of digester (i.e., volume of liquid inside the digester) (m^3)

M_p : amount of methane produced (m^3)

M_y : methane yield ($m^3\ kg^{-1}$)

2.5 Validation and evaluation

The validation of a software application aims at determining whether the software is running properly. Additionally, the evaluation of a software application aims to determine its accuracy. The data acquired were used to perform the computations using the conventional method to deliver results which were compared with the results computed by the developed software application. The results of both the conventional method and the software application must be indistinguishable.

2.6 Software

MIT App Inventor is a web application integrated development environment initially developed by Google, and currently is supported by the Massachusetts Institute of Technology (MIT). It implements a graphical user interface (GUI) analogous to the programming languages Scratch (programming language) and the StarLogo, which support users in dragging and dropping visual objects to make an application that can operate on android-supported cell phones with an App-Inventor Companion which is the software that supports the cell phone application to run and debug on.

3 Results

The developed software application can size the anaerobic digesters and compute the energy production and biogas and methane yields. The results of the programming are presented in Figures 13-16, where the input and output data are displayed. The cell phone application was designed in a manner that when the input data are inserted, then the size of the anaerobic digester and the energy produced as well as the biogas and methane yields will appear, automatically. The figures can be described as follows: Figure 13 shows the main creen of the cell phone application, Figure 14 shows the input and output data screen for sizing anaerobic digesters, Figure 15 shows the input and output data screen for estimation of energy production from a substrate, Figure 16 shows the input and output data screen for estimation of biogas and methane yields.

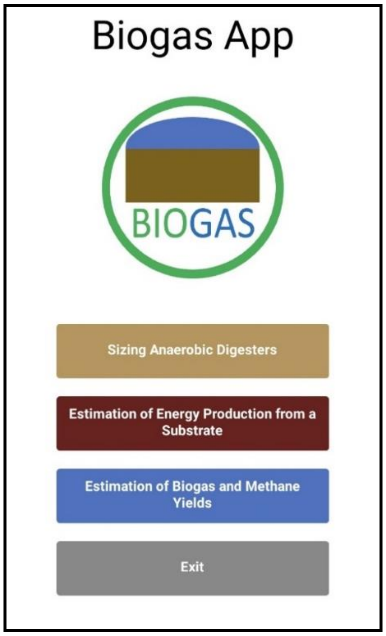

Figure 13 Main screen of the cell phone application

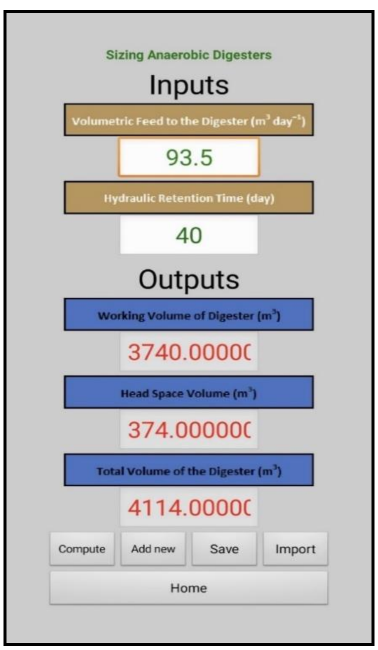

Figure 14 Input and output data screen for sizing anaerobic digesters

Figure 15 Input and output data screen for estimation of energy production

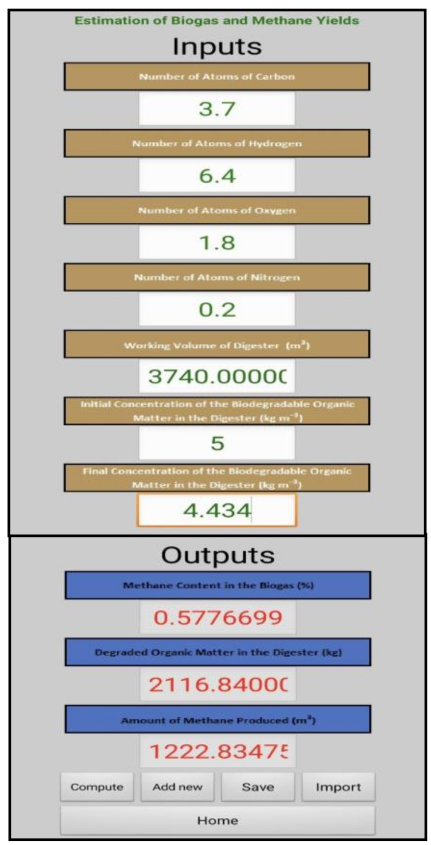

Figure 16 Input and output data screen for estimation of biogas and methane yields

4 Discussion

The gathered data were employed to perform the calculations using the conventional method to deliver results which were compared with the results computed by the developed software applications. The results of the conventional method and the software were indistinguishable. Hence, the developed software applications can be used effectively to size the anaerobic digesters and compute the energy production as well as the biogas and methane yields. The benefits of the developed software application can be briefed as follows: it can be easily used by non-professionals such as students and practitioners, it has a small size, it is capable to work updates, it is easy to download and run, it can be easily operated by students within the learning process.

4.1 Programming concepts and characteristics

This software application was configured using two programming models. The first model is implementing the structured systems analyses and design methods which discourse the technical characteristics of system development by dividing it into smaller sections, each section consists of a sequence of steps, each step encompasses several procedures, and each procedure consists of several duties. The second programming model is the use of MIT App Inventor to buffer the software system from the elements to overall processes.

4.2 Structured induction

Know-how acquisition was recognized as the restriction of developing a software application. Structured induction presents a technique for acquiring and formalizing know-how. Induction is opposing the deduction; a common technique whereby general knowledge is applied to a particular problem to overcast results. Induction uses particular cases and creates general knowledge which is consistent with these cases. Using a set of cases, rules indicating fundamental knowledge can be drawn, and structured into a decision tree in form of a flowchart, known as electronic spark map. The decision tree can then be developed into a functional knowledge base for a software application. Structured induction uses a set of scenarios and applies a mathematical algorithm to them. The outcome is an electronic spark map, optimized corresponding to programmed norms, with descriptive traits at each branch node and a decision at each terminal node. An electronic spark map conveys the know-how included in the set of cases in an arranged and effective configuration. Since many spark maps are viable for a certain set of cases, optimization must be conducted to get the most effective decision possible; this was accomplished by means of actual values acquired from several biogas units and comparing them with the values computed by the software application. Knowledge acquisition and formalization using structured induction in which an induction algorithm was applied to originate rules. Sensitive parameters, dependent variables, and constant values of a developed algorithm were configured to be inserted as input/output data of the relevant spark map and later to configure its interface. Induction structures the declarative data to reduce some degrees of ambiguity in the spark map configuration. Induction is a compelling tool for software application development. However, it should be considered as one of several approaches for knowledge acquisition. Individual dialogue between domain specialists and the Artificial Intelligence Engineer is a crucial section in the process. When implemented correctly by the Artificial Intelligence Engineer, induction can offer structured knowledge representing genuine experience.

4.3 Educational Effect

The developed software application can be employed as a computer-based training (CBT), which is a type of education in which the student learns by completing special training programs. Accordingly, the developed software application can be incorporated within the biogas training courses so that learners can exercise using the application as they learn. Increasing users' decision-making capability beyond their former education and expertise have positive influences. Specifically, when software applications are principally based on current publications typically include know-how delivery. The configured software application represents this effect.

4.4 End users

This cell phone application is addressed to engineers, farmers, specialists, and non-specialists in biogas production processes, students in practical study, and in research experiments for scientists.

5 Conclusion

A mathematical model was developed to size the anaerobic digesters and compute the energy production as well as the biogas and methane yields. Then, an electronic spark map was configured, and the mathematical model was incorporated into the spark map. Afterwards, MIT App Inventor was used to develop a software application by combining the electronic spark and the mathematical model and creating the user interface. Data was acquired from governmental institutions, farms, non-governmental organizations (NGOs), and literature. The data acquired was used to perform the calculations using the conventional method to produce results which were compared with results computed by the developed software application. The results of the conventional method and the software were indistinguishable. Hence, it can be concluded that the configured software application can be implemented effectively for sizing the anaerobic digesters and computing energy production and biogas and methane yields.

Acknowledgments

The authors acknowledge the Science and Technology Development Fund (STDF) of Egypt for supporting this study through the project number 30278, which is a subpart of the international project EranetMed Biogasmena (ID 72-026).

References

Abdelsalam, E., M. Samer, M. A. Abdel-Hadi, H. E. Hassan, and Y. Badr. 2018. Influence of laser irradiation on rumen fluid for biogas production from dairy manure. *Energy*, 163: 404-415.

Abdelsalam, E., and M. Samer. 2019. Biostimulation of anaerobic digestion using nanomaterials for increasing biogas production. *Reviews in Environmental Science and Biotechnology*, 18(3): 525-541.

Abdelsalam, E., M. Samer, Y. Attia, M. A. Abdel-Hadi, H. E. Hassan, and Y. Badr. 2019. Effects of laser irradiation and Ni nanoparticles on biogas production from anaerobic digestion of slurry. *Waste and Biomass Valorization*, 10(11): 3251-3262.

Abdelsalam, E., O. Hijazi, M. Samer, I. H. Yacoub, A. S. Ali, R. H. Ahmed, and H. Bernhardt. 2019. Life cycle assessment of the use of laser radiation in biogas production from anaerobic digestion of manure. *Renewable Energy*, 142: 130-136.

Abdelsalam, E. M., A. El-Hussein, and M. Samer. 2021. Photobiostimulation of anaerobic digestion by laser irradiation and photocatalytic effects of trace metals and nanomaterials on biogas production. *International Journal of Energy Research*, 45(1): 141-150.

Attia, Y. A., M. I. Kobeasy, and M. Samer. 2018. Evaluation of magnetic nanoparticles influence on hyaluronic acid production from *Streptococcus equi*. *Carbohydrate Polymers*, 192: 135-142.

Attia, Y. A., M. Samer, M. A. Moselhy, A. H. Arisha, A. A. Abdelqader, and E. Abdelsalam. 2021. Influence of laser photoactivated graphitic carbon nitride nanosheets and nickel nanoparticles on purple non-sulfur bacteria for biohydrogen production from biomass. *Journal of Cleaner Production*, 299: 126898.

Broner, I., J. P. King, and A. Nevo. 1990. Structured induction for agricultural expert systems knowledge acquisition. *Computers and Electronics in Agriculture,* 5(2): 87-99.

El Mashad, H., and R. Zhang. 2020. Biogas energy from organic wastes. In *Introduction to Biosystems Engineering*, eds. N. M. Holden, M. L. Wolfe, J. A. Ogejo, and E. J. Cummins, 1-23. USA, The American Society of Agricultural and

Biological Engineering (ASABE) & Verginia Tech Publishing.

Giarratano, J. C., and G. Riley. 2005. *Expert Systems: Principles and Programming*. **4th ed**. Boston, Mass: Thomson Course Technology.

Greer, J. E., S. Falk, K. J. Greer, and M. J. Bentham. 1994. Explaining and justifying recommendations in an agriculture decision support system. *Computers and Electronics in Agriculture*, 11(2-3): 195-214.

Hijazi, O., E. Abdelsalam, M. Samer, Y. A. Attia, B. M. A. Amer, M. A. Amer, M. Badr, and H. Bernhardt. 2020a. Life cycle assessment of the use of nanomaterials in biogas production from anaerobic digestion of manure. *Renewable Energy*, 148: 417-424.

Hijazi, O., E. Abdelsalam, M. Samer, B. M. A. Amer, I. H. Yacoub, M. A. Moselhy, Y. A. Attia, and H. Bernhardt. 2020b. Environmental impacts concerning the addition of trace metals in the process of biogas production from anaerobic digestion of slurry. *Journal of Cleaner Production*, 243: 118593.

Ioannou-Ttofa, L., S. Foteinis, A. S. Moustafa, E. Abdelsalam, M. Samer, and D. Fatta-Kassinos. 2021. Life cycle assessment of household biogas production in Egypt: Influence of digester volume, biogas leakages, and digestate valorization as biofertilizer. *Journal of Cleaner Production*, 286: 125468.

Samer, M. 2010. A software program for planning and designing biogas plants. *Transactions of the ASABE*, 53(4): 1277-1285.

Samer, M., C. Loebsin, K. von Bobrutzki, M. Fiedler, C. Ammon, W. Berg, P. Sanftleben, and R. Brunsch. 2011. A computer program for monitoring and controlling ultrasonic anemometers for aerodynamic measurements in animal buildings. *Computers and Electronics in Agriculture*, 79(1): 1-12.

Samer, M. 2012. Biogas plant constructions. In *Biogas*, ed. S. Kumar, 343-368. London, United Kingdom: InTech.

Samer, M., M. Hatem, H. Grimm, R. Doluschitz, and T. Jungbluth. 2012. An expert system for planning and designing dairy farms in hot climates. *CIGR Journal*, 14(1): 1-15.

Samer, M., M. Hatem, H. Grimm, R. Doluschitz, and T. Jungblut. 2013. Software for planning loose yards and designing concrete constructions for dairy farms in arid and semi-arid zones. *Emirates Journal of Food and Agriculture*, 25(3): 238–249.

Samer, M. 2015a. *Wastewater Treatment Engineering*. London, United Kingdom: InTech.

Samer, M. 2015b. GHG emission from livestock manure and its mitigation strategies. In *Climate Change Impact on Livestock: Adaptation and Mitigation*, eds. V. Sejian, J. Gaughan, L. Baumgard, and C. Prasad, 321-346. Germany: Springer Internationa.

Samer, M., K. Helmy, S. Morsy, T. Assal, Y. Amin, S. Mohamed, M. Maihoob, M. Khalil, I. Fouda, and A. Abdou. 2019. Cellphone application for computing biogas, methane and electrical energy production from different agricultural wastes. *Computers and Electronics in Agriculture*, 163: 104873.

Samer, M., O. Hijazi, E. M. Abdelsalam, A. El-Hussein, Y. A. Attia, I. H. Yacoub, and H. Bernhardt. 2021. Life cycle assessment of using laser treatment and nanomaterials to produce biogas through anaerobic digestion of slurry. *Environment, Development and Sustainability*, 23(10): 14683-14696.

Samer, M., E. M. Abdelsalam, S. Mohamed, H. Elsayed, and Y. A. Attia. 2022a. Impact of photoactivated cobalt oxide nanoparticles addition on manure and whey for biogas production through dry anaerobic co-digestion. *Environment, Development and Sustainability*, 24(6): 7776-7793.

Samer, M., S. S. Abdeen, Y. B. Abd Elhay, and K. Abdelbary. 2022b. Cell phone application for kinetic modeling and computing biohydrogen yield and production rate from agricultural wastes. *Computers and Electronics in Agriculture*, 201: 107288.

Samer, M., B. A. Mohamed, S. S. Abdeen, And K. Abdelbary. 2023. Biobutanol and bioethanol production from agricultural wastes: A cell phone application for computing the bioconversion rates. *CIGR Journal*, 25(3): 181-200.

Yoo, K. H. 1989. Application of dynamic programming in agricultural engineering problems. *Applied Engineering in Agriculture*, 5(2): 180-184.