# Development of software tool for solar thermal energy applications to Dairy industry

Prof. N G. Ajjanna[1], Dr.H.B. Suresh[2,] Dr.L.K. Sreepathi[3]
[1]*Asst.professor, Ph.D. scholar, Dept. of E&E, JNNCE, Shimoga, Karnataka, India*
[2] *Professor, Dept. of E&E, JNNCE, Shimoga, Karnataka, India.*
[3] *Visiting professor at IIT Dharwad, Karnataka, India.*

***Abstract— the dairy industry's demand for processing milk and milk products has been steadily increasing due to population growth, making thermal energy essential. Solar energy is widely utilized in dairy processing activities such as heating, steam production, cooling, drying, pumping, and cleaning. This paper focuses on developing specialized software tool to optimize the use of solar thermal energy in the dairy industry. An application software tool has been created in the python language using the pycharm platform to facilitate the integration of solar thermal systems for dairy, enabling sustainable energy solutions and cost savings. The software provides valuable insights into system design, economic feasibility, and estimation of co₂ reduction. To validate the application software, a case study was conducted at Shimoga milk union limited (SHIMUL) dairy in Shimoga, Karnataka, India. The results obtained by the software perfectly matched the theoretical calculations. While the analysis is focused on the dairy industry, the software tool developed can be utilized for solar thermal applications in any industry.***

***Keywords— Solar Thermal Energy, Software Tool, Payback Period, Reduction in Carbon Emission***

## I. INTRODUCTION

In a world increasingly focused on sustainability and renewable energy sources, the dairy industry is no exception.The dairy industry plays a vital role in the global food supply chain, but it is also energy-intensive, relying heavily onconventional fossil fuel-based energy sources. Solar thermal energy, with its capacity to harness the sun's abundant energy [1].

Considering the climate crises associate with the harmful gas emissions, the renewable energy technologies become one of the fastest developing sectors across the world. Solar energy as well established renewable energy has been used for space heating, domestic hot water and electricity generation. Food industry is the one of the most promising industry for the solar energy applications, particularly dairy industry, due to thermal heating and cooling requirements. Milk production, processing and marketing activities utilize a lot of thermal energy, which is mostly derived from traditional energy sources, causing pollution and contributingto climate change [2]. Solar energy has a wide range of uses in dairy processing activities such as heating, steam production, cooling, drying, pumping and cleaning [4].

This paper endeavors to address this critical need by focusing on the development of specialized software. Through precise system modeling, optimization, and economic analysis, it offers a comprehensive toolkit to maximize the benefits of solar thermal solutions while minimizing operational costs and environmental impact. This paper, presents a combined energy, economic, and environmental analysis of an optimally sized and configured solar water heating system for the thermal energy requirements of dairy industry [10]. To ensure the theoretical calculation align with real word performance, the software could include features for monitoring and validation system performance

over time this could involve collecting data from industry and comparing it with theoretical prediction to access accuracy and identify areas for improvement. The analysis starts with selection of solar heating system to avoid oversize and to obtain the minimum total yearly operation cost, which includes capital, maintenance operation, and environmental costs [9]. The analysis is useful for designers' powerful tool for planning, designing, optimizing, and monitoring solar thermal energy systems, while ensuring alignment with theoretical principles and calculations.

## II. ABOUT THE SHIMUL

Figure 1 depicts the image of SHIMUL dairy. In Shivamogga Town, Govt milk scheme started on 21st May 1971 under the department of Animal Husbandry. Dairy Unit having facilities to process and bottle 10,000 liters per day.

Figure 1 Shimul dairy Industry The said facility was handed over to KMF in the year 1985 and Shivamogga Co-op Milk Union in the year 1991 as per Govt Orders from time to time. Shivamogga Co-operative Milk Union Limited is located at survey No. 72(118), Nidige Panchayat at Machanahalli, having sprawling area of 25.35 acres of land. It manufactures 8 dairy products and markets other products of KMF in its jurisdiction. Shimul is growing herbal medicinal plants on Shivamogga Dairy premises. SHIMUL started its functioning on 16-03-1988, committed to producer's welfare through customer delight adopting continuous improvement and ensures pure and hygienic milk & milk product

## III. LITERATURE SURVEY

In this article, an extensive review of various solar thermal energy technologies and their industrial applications are presented. The following industries are covered: power generation, oil and gas, pulp & paper, textile, food processing & beverage, pharmaceutical, leather, automotive, and metal industries. For each of the applications, quality and quantity of heat requirements are identified. [1]

This paper analysis of the current energy world scenario draws on the combination of energy efficiency improvement and the use of renewable-type energies. The industrial use of renewable energies is not still well established as they present several problems that generate insecurity in this sector [3]. This study critically evaluates the thermal demands of the dairy processes, reviews their existing solar thermal applications and recommends a concept design for solar thermal energy integration based onthe available data [5].

This paper as more and more domain specific big data become available, there comes a strong need on the fast development and deployment of deep learning (DL) systems with high quality for domain specific applications, including many safety-critical scenarios. In traditional software engineering, software visualization plays an important role to enhance developers' performance with many tools available [10]

## IV. METHODOLOGY

Methodology used for development of software:

Step-1: Detailed study and data collection from industry: To validate the application software developed a case study is carried out at Shimoga Milk Union Limited (SHIMUL) dairy, Shimoga.

Secondary data collected from Shimul:

Energy density, calorific value, amount of fuel required, cost of fuel, co2 emission, total investment.

Step-2: Selection of fuel: After studying and data is collected from industry. An algorithm is developed for calculations. related to the design solar thermal energy and all the theoretical calculations of the design were carried out.

Step-3: Development of application software: code is written to develop a computer program using the python programming language, which could accept the required inputs from the user and provide a details. To make the program more interactive and easily accessible for the user, the developed Software tool estimates the calorific value, amount of fuel required, amount of carbon reduction, payback period.

Step-4: Validation of application software: The results obtained by the software are exactly matching with theoretical calculation.

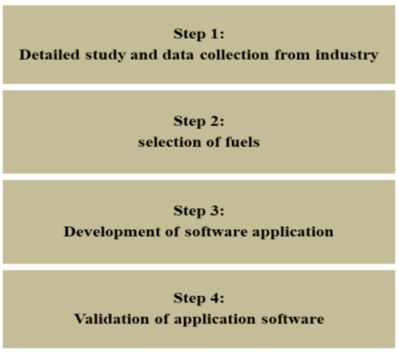


Figure 2: Methodology used for development of software:

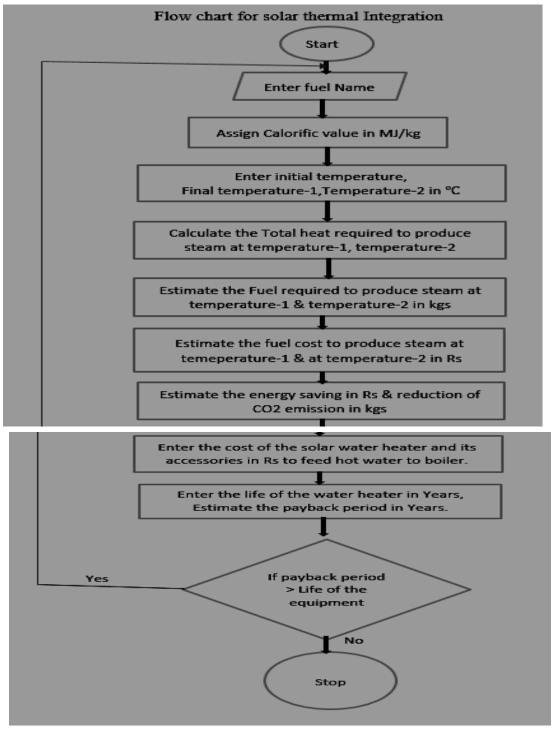

Figure 3: Flow chart for solar thermal integration

## V. INPUT TO SOFTWARE TOOL

To run the software, to determine the amount of fuel, payback period, reduction in CO2 emission. Enter the input as per the format mentioned in figure 4.

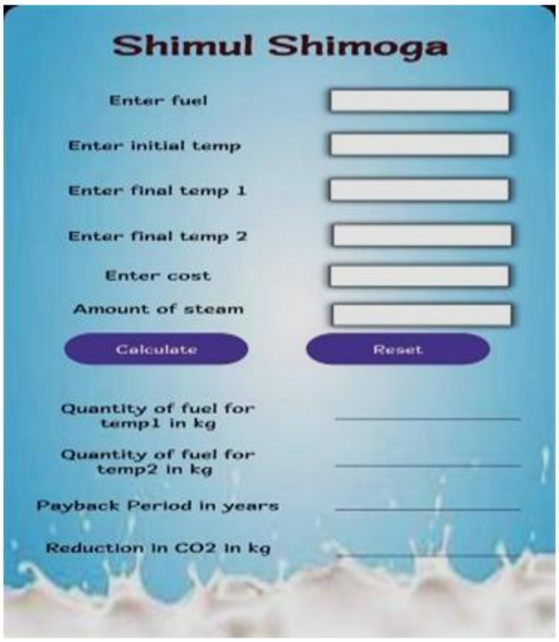

FIGURE 4: INPUT FORMAT

## VI. SAMPLE CALCULATION

Sample calculation is given for illustrating the various steps involved in manual calculation of solar thermal application and also helpful for validation of software tool with theoretical calculation.

- FUEL FOR BOLIER INPUT = COAL
- Energy density of the coal in J/Kg = 3,26,00,000
- TOTAL HEAT REQUIRED TO PRODUCE STEAM AT 180°C IN JOULES = HEAT ABSORBED BY WATER TO REACH 180°C+LATENT HEAT OF VAPORIZATION = [4186*(180-25)] + (2260000J) WATER INLET TEMPERATURE IS ASSUMED 25°C= 29,08,675 JOULES.
- Total heat required to produce steam at 65°c in joules = heat absorbed by water to reach 40°c (65-25) + latent heat of vaporization = [4186*(65-25)] +2260000j) water inlet temperature assumed 25°c = 24,27,440 joules
- (0.9*energy density) in joules=29,340,000

  AMOUNT OF FUEL REQUIRED IN KG TO PRODUCE 1KG OF STEAM AT 180 °C $= \frac{\text{Total heat required in joules}}{\text{0.9Xenergy density of fuel}} =$ 0.10 KG
- Amount of fuel required in kg to produce 1kg of steam at 65 °c $= \frac{\text{Total heat required in joules}}{\text{0.9Xenergy density of fuel}}$ = 0.08 kg
- AMOUNT OF FUEL REQUIRED IN KGS PER ANNUM TO PRODUCE 50 TONNES OF STEAM PER DAY 180°C= 1,809,247 KGS
- Amount of fuel required in kgs per annum to produce 50 tonnes of steam at 65°c = 452,312kgs
- COST OF FUEL IN RS /KG= RS 9.6 / KG
- Net fuel cost per annum = [(cost/kg of fuel*amount of fuel required to produce 50 tonnes of steam at 180°c) *365] = rs 17,368,775
- NET FUEL COST PER ANNUM = [(COST/KG OF FUEL*AMOUNT OF FUEL REQUIRED TO PRODUCE 50 TONNES OF STEAM AT 65°C) *365] = RS 4,481,144
- Co2 emission in kg/annum= (amount of fuel required in kg*co2/kg) = 1,524,291kg

TOTAL INVESTMENT ON HOT WATER AND ACCESSORIES TO SUPPLY 50,000-LITER HOT WATER PER DAY = (COST OF WATER HEATER*NUMBER OF WATER HEATERS REQUIRED+ACCESOROIES+SALARY TO WATER HEATER MAINTENANCE) = RS 10,460,000

- Payback period in years = 2.3 years

TABLE 1: SAMPLE TABLE FOR TABULATION OF SAVINGS, PAYBACK PERIOD AND REDUCTION OF CO2 FOR FUEL COAL.

| Fuel | Energy density in J/Kg | TH=Total heat required to produce 1kg of steam at 180°C | TH=Total heat required to produce 1kg of steam at 65°C | G = Fuel require to produce Steam 80°C per day |
|---|---|---|---|---|
| Coal | 3,26,00,000 | 29,08,675 | 24,27,440 | 18,09,247 |
| H = Fuel required to produce steam at 65°C per day | K= CO2 emission in kgs/annum without solar thermal energy | CO2 emission in Kgs/annum with solar plant | L = Total investment for boiler & its Accessories. | P = payback period in years |
| 4,52,312 | 60,97,164 | 15,24,291 | 1,04,60,000 | 2.334 |

The sample calculation above estimates the total heat required to produce steam at a specific temperature. It is necessary for calculating economic and environmental benefits and finding a payback period. Repeated calculations are necessary if the calorific value of the fuel changes, or if different fuels are used for the same purpose. Calculations also need to be repeated if the cost per kilogram of fuel changes, or when there are changes in steam temperature or the quantity of steam. However, manual calculations are time-consuming and can result in errors. To avoid these issues, a software tool has been developed.

## VII. COMPUTER PROGRAM

```
EC=32600000
ED=45600000
EL=49300000
EB= 28600000
fuel=input ("Enter fuel:")
co2=3.37
Total investment=10460000
if(fuel=="coal"):
EE=EC
if(fuel=="Diesel"):
EE=ED
if(fuel=="LPG"):
EE=EL
if(fuel=="Briquettes"):
EE=EB
t1=int (input ("Enter initial temperature:"))
t21=int (input ("Enter final temperature 1:"))
t22=int (input ("Enter final temperature 2:"))
cost=float (input ("Enter the cost of fuel:"))
#Total heat required in joules = heat absorbed by water to reach 180°C+Latent heat of vaporisation = [4186*(180-25)] +2260000J) water inlet temperature assumed 25°C
D=(4186*(t21-t1)) +2260000
#Total heat required in joules = heat absorbed by water to reach 40°C+Latent heat of vaporisation = [4186*(65-25)] +2260000J) water inlet temperature assumed 25°C
E=(4186*(t22-t1)) +2260000
# (0.9*Energy density) in Joules
F=0.9*EE
#Amount of fuel required per day in kg to produce 1kg of steam at 180 °C = Total heat required/ (0.9Xenergy density of fuel)
G=round(D/F,3)
#Amount of fuel required in kg to produce 1kg of steam at 65 °C = Total heat required/ (0.9Xenergy density of fuel)
H=round(E/F,3)
#Amount of fuel required in kgs per annum to produce 50 tonnes of steam per day 180°C
I=G*50000*365
#Amount of fuel required per annum in kgs produce 50 tonnes of steam at 65°C
J=I*0.25
#cost of fuel in Rs /kg
K=cost
#Net fuel cost per annum = [(cost/kg of fuel*Amount of fuel required to produce 50 tonnes of steam at 180°C*365]
L=I*K
#Net fuel cost per annum = [(cost/kg of fuel*Amount of fuel required to produce 50 tonnes of steam at 65°C) *365]
M=L*0.258
```

#Co2 emission in kg/ annum= (amount of fuel required in kg*Co2/kg)
N=J*co2
#Total investment on hot water and accessories to supply 50,000 litre hot water per day = (cost of water heater*number of water heaters required+accesoroies+salary to water heater maintenance)
O=Total investment
#payback period in years
P=round(O/M,3)
print (D, E, F, G, H, I, J, K, L, M, N, O, P)

## VIII. RESULT AND DISCUSSION

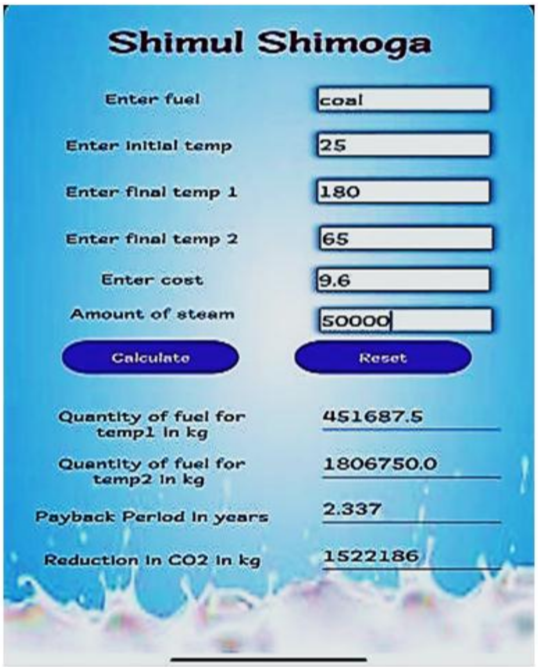


*Figure 5: sample of output of Software with inputs.*

Figure 5 displays the sample output of software tool developed. The software tool is created to calculate parameters such as the amount of fuel needed in kilograms at temperatures 1 and 2, where t1 and t2 represent initial and final temperatures respectively. Additionally, the software tool estimates the payback period for solar thermal systems and the reduction in CO2 emissions. It can be utilized for various fuels, different temperatures, and varying amounts of steam for solar thermal energy applications. Analysis of the software output has consistently aligned with theoretical models and provided further insights, offering potential economic and environmental benefits. This software tool, tailored for the dairy industry, can be applied to all industries interested in utilizing solar thermal energy to reduce boiler input.

## CONCLUSION

Integrating a solar thermal energy system with a conventional boiler can reduce environmental pollution and provide economic benefits. Determining the rating of the solar thermal system in conjunction with the conventional boiler, considering a specific energy source with a particular calorific value, allows us to estimate economic benefits, CO2 emission reduction, and calculate the return on investment. Performing these calculations manually can be time-consuming, less reliable, and prone to errors. To streamline this process and improve accuracy, a software tool has been developed. This software will be beneficial for solar thermal system designers.

## ACKNOWLEDGMENT

The authors cordially wish to thank the officers of SHIMUL dairy for their support during the collection of data and its analysis. The authors also wish to acknowledge the encouragement and support provided by the faculty and staff of E&E dept. HOD of E &E Dept. JNN College of Engineering during the preparation of this paper.

BIOGRAPHIES:

N G Ajjanna

Received a bachelor's degree in Electrical and Electronics Engineering from Kuvepu University in 1995, and a master's degree in Energy System engineering from Visvesvaraya Technological University in 2001. He is currently doing Research work in the field of Energy Management. Working as an Assistant Professor at the Department of Electrical and Electronics Engineering and coordinator of 400KW RTSPV system installed at JNNCE, Shimoga. His interesting areas include Energy Auditing, Energy conservation, DSM Techniques, and Renewable Energy Technologies. He has authored and published a Textbook on Energy Auditing and Demand Side Management.

Dr. H.B. Suresh

Received his B.E. degree in electrical and electronics engineering from Mysore University, India, and his

M.E. in energy system engineering from Karnataka University, India. He pursued his Ph.D. program at Jawaharlal Nehru Technological University, India. Currently, he is working as a professor in the electrical and electronics engineering department, at JNNCE, Shimoga. He has presented various papers at conferences in India and published twelve papers in national and international journals and conference proceedings. Currently is guiding two candidates for the Ph.D. program. He is the coordinator for Biofuel Research, Information and Demonstration Centre (BRIDC), JNNCE, funded by Govt. of Karnataka. His areas of interest are sustainable energy technologies, energy conservation, and management, and renewable energy resources. He has delivered more than 100 invited technical talks.

Dr. L.K. Sreepathi

Received his B.E. degree in mechanical engineering from Bangalore University India in the year 1985. He pursued his M. Tech and Ph.D. programs at IIT Bombay from 1988 to 1994 in the area of thermal and fluid engineering. He is the former Vice-Principal of JNN College of Engineering, Shimoga, currently working as visiting professor and green energy coordinator at IIT Dharwad, Karnataka India. He has carried out several research projects funded by CSIR, MNES, AICTE. His areas of interest are biomass gasification, passive cooling of the building, solar energy, rainwater harvesting, etc. He has successfully guided five Ph.D. students. Currently is guiding two candidates for the Ph.D. program. He has presented papers at various conferences in India and abroad and has published more than twenty-five papers in national and international journals and conference proceedings. He was the coordinator for the Chiranthana Green Technology Centre. Currently he is working as visiting professor at IIT Dharwad, Karnataka, India.

## REFERENCES


[1] Ravi Kumar K, Krishna Chaitanya N.V.V, Sendhi Kumar Nataraja. “SOLAR THERMAL ENERGY TECHNOLOGIES AND ITS APPLICATIONS FOR PROCESS HEATING AND POWER GENERATION” Volume 282,1 February 2021, 125296

[2] Alka Solanki, Yash PAL. “A COMPREHENSIVE REVIEW TO STUDY AND IMPLEMENT SOLAR ENEGY IN DAIRY INDUSTRIES” Year 2021, Volume:7 Issue:5, 1216-1238

[3] Jose Antenio Quijera, Maria Gonzalez Alriols, Jalel Labidi. “INTEGRATION OF SOLAR THERMAL SYSTEM IN A DAIRY PROCESS”. Volume 36, Issue 6, June 2019, pages 1843-1853

[4] Kemal Masera, Hadi Tannous, Savvas Tassou, Valentina, Stojceka. “APPLICATION OF SOLAR THERMAL ENERGY TO DAIRY INDUSTRY”

[5] Kemal Masera, Hadi Tannous, Savvas Tassou, Valentina, Stojceka, Savvas Tasssou. “AN INVESTIGATION Of THE RECENT ADVANCES OF THE INTEGRATION OF SOLAR THERMAL ENERGY SYSTEMS TO THE DAIRY PROCESS”. Volume 172, February 2023, 113028

[6] Chaimaa EI Mkadmi, Arifeen Wahed. “OPTIMIZATION OF A SOLAR THERMAL SYSTEM FOR LOW TEMPERATURE INDUSTRIAL HEATING PROCESS”. Publisher: IEEE, 2016 international Renewable and sustainable energy conference

[7] Fitsum Bekele tilahun, Mengesha Mamo. “OPTIMAL SOLAR FIELD AND THERML STORAGE SIZING IN HYBRID SOLAR BIOMASS COGENERATION PLANT”. Publisher: IEEE, 2020 IEEE PES/IAS Power Africa

[8] Badreddine Boutaghriout, AMina Bouakaz. “INVESTIGATION ON THE USE OF SOLAR THERMAL ENERGY IN THE AGRO FOOD INDUSTRY IN ALGERIA”. Publisher: IEEE. 2018 international Renewable and sustainable energy conference.

[9] Yara Haddad, Ibrahim Rahoma; Firas Obeidat; “MODELLING OF A SOLAR HEATING SYSTEM FOR INDUSTRIAL PROCESSES USING LINEAR FRESNEL REFLECTORS”. Publisher: IEEE Mokhta. 2022 13th International Renewable Energy Congress.

[10] Qiang Hu; Lei Ma, Jianjun Zhao “DEEPGRAPH: A PYCHARM TOOL FOR VISUALIZING AND UNDERSTANDING DEEP LEARNING MODELS”., Publisher: IEEE. 2018 25th Asia-Pacific Software