DOST Form 2 (for Basic/Applied Research)

# DETAILED RESEARCH & DEVELOPMENT PROJECT PROPOSAL

**(1) PROJECT PROFILE**

Program Title: Local Grant-in-Aid
Project Title: Design and Development of Fuel-Efficient Kiln for salt bed tiles
Project Leader/Sex: Ken Angelo M. Vivas / Male
Project Duration (number of months): 12 months for project implementation / 24 months for monitoring of outcomes
Project Start Date: January 2024
Project End Date: May 2027
Implementing Agency (Name of University-College-Institute, Department/Organization or Company):
Occidental Mindoro State College-Main Campus
Address/Telephone/Fax/Email (Barangay, Municipality, District, Province, Region):
Barangay Labangan Poblacion, San Jose, Occidental Mindoro

**(2) COOPERATING AGENCY/IES** (Name/s and Address/es)
Occidental Mindoro State College, San Jose, Occidental Mindoro

**(3) SITE(S) OF IMPLEMENTATION**

| IMPLEMENTATION SITES NO. | COUNTRY | REGION | PROVINCE | DISTRICT | MUNICIPALITY | BARANGAY |
|---|---|---|---|---|---|---|
| 1. | Philippines | MIMAROPA | Occ. Mdo | Lone | San Jose | Mapaya |

**(4) TYPE OF RESEARCH**
____. Basic
__✓__. Applied

**(5) R&D PRIORITY AREA & PROGRAM (based on HNRDA 2017-2022)**
____ Agriculture, Aquatic and Natural Resources
Commodity: _____
____ Health
Priority Topic: _____
__✓__. Industry, Energy and Emerging Technology
Sector: Agriculture
____ Disaster Risk Reduction and Climate Change Adaptation
____ Basic Research
Sector: _____

**Sustainable Development Goal (SDG) Addressed**: INDUSTRY INNOVATION AND INFRASTRACTURE

**(6) EXECUTIVE SUMMARY** (not to exceed 200 words)

This project proposal focuses on the development of cross-draft kiln purposely for the fabrication of salt bed tiles for the salt farmers in the province of Occidental Mindoro. Kilns are industrial ovens designed to fire clay products at optimum temperature. Over the years, the design of kilns have evolved to meet the specific material processing needs, improved the thermal efficiency, and address environmental considerations. This project aims to provide an efficient design for kiln responding to the needs of salt farmers as energy and material consumption of existing kilns in the province provided limited opportunities for mass production of salt bed tiles. The proposed cross-draft kiln is design to ensure the uniform distribution of heat in the cooking chamber with less fuel consumption; with its rectangular-shaped salt bed tiles oven enclosed with metal sheet, heat insulation can be achieved. Further, the proposed cross-draft kiln is equipped with programmable unit to offer an automated control of firing operations and air-flow mechanism it also includes the participation of men and women to achieve safe operations, efficient fuel consumption, sustainable and environment friendly and optimum production capacity kiln.

**(7) INTRODUCTION**

**(7.1) RATIONALE/SIGNIFICANCE** (not to exceed 300 words)

Occidental Mindoro was considered as one of the two biggest salt producers in the country contributing to approximately 18% (60,000 MT) of the country's total salt requirement of 338,000MT (DOST, 2017). But a factor affecting the salt production in the province causes the decline and placed the salt industry in a thriving situation. The changing climate conditions, environmental factors, declining labor workforce and availability of materials for salt beds are considered as the major players triggering the reputation of the province in salt industry. Most of the salt ponds in the province still uses the traditional evaporation ponds with salt beds made up of tiles laid purposely to store the salt water, and provides an area for crystallization to occur and where harvesting of salt crystals took place. Clay tiles prevents the salt from coming into contact with the soil and avoid the intrusion of impurities in the white crystals. Therefore, salt bed tiles are vital components of salt farms that need to be examined to determine its capability to yield maximum production and good quality. Salt beds tiles or commonly known as "tisa" is a product of an oven-dried or kiln dried clay. At present there are almost 35, 000 salt beds in the province (TAMACO,

2023). Most of the clay tiles were from Ilocos Region but the province is now facing insufficient sources of raw materials: Vigan clay and the woods for kiln and as triggered by the shifting of traditional pottery to plastic technology. These problems were felt by the local salt producers as Vigan tiles are gradually disappearing. At most, 750 kilos of tiles is needed for a new salt bed; and an average of 2-3% for very three years tile replacement. But the availability of the kiln and furnaces are limited in the province and feedbacks from the users of local tiles stated weak property of the clay tiles to resist the salt intrusion and tend to pulverize in a small period of time. As the salt industry embraces the development of technology to optimize the salt production processes, one possible solution is the development of a fuel-efficient kiln to sustain the needs for salt bed tiles. This prompted the development of the proposed fuel-efficient cross-draft kiln that can offer an automated system considering the uniform heat distribution and optimum production capacity.

**(7.2) SCIENTIFIC BASIS/THEORETICAL FRAMEWORK**

This study is based on the request of the salt farmers in Occidental Mindoro with the ultimate objective of producing clay tiles for salt bed needs in the province. Driven with the desire to respond to the increasing needs in the salt bed tiles, the proposed design considered existing kilns and the limitation they offer that opted farmers to procure the so-called Vigan clay tiles. As the Vigan clay tiles are becoming obsolete due to the scarcity in the raw materials, salt farmers are starting to look for additional sources of salt bed tiles. A promising opportunity is offered by the abundant source of red clay tiles in the province, however, a sustainable and efficient kiln for mass production is needed to fire up the clay and produce the desired quality of salt bed tiles.

The proposed designed of fuel-efficient cross-draft kiln considered existing kilns that uses LPG-ignition burner, electrically operated kiln and wood-fired kilns. Eventually, these kilns were not sustained as economic cost hinders the full utilization of the existing kilns. This project proposal is micro-controlled to ensure efficient flow and uniform distribution of heat in the cooking chamber. By utilizing gas as a fuel source, this gas kiln offers higher efficiency compared to traditional kilns that uses lumber or wood. It achieves this efficiency by mixing fuel gas with air in the correct proportions to generate a high-temperature flame, ensuring uniform heating within the kiln chamber. Modern gas kiln burners often feature advanced temperature control mechanisms, allowing precise adjustments for specific temperature profiles. The proposed project also has safety features such as flame sensors and automatic shut-off systems to ensure reliable flaming operation. The proposed kiln is equipped with PLC in the control circuits that serve as the brain of the automatic operations and manage the various sensors such as temperature sensors to monitor the internal and external temperature; and the pressure sensors for the monitoring of the combustion and air-flow levels. By continuously analyzing data from these sensors, the PLC will make a real-time adjustments to optimize the machine's performance. This results in enhanced firing process efficiency, precise fuel consumption control, and improved product quality. The integration of PLC technology ensures reliable and intelligent automation, streamlining the process and delivering consistent, high-quality results.

**(7.3) OBJECTIVES**

Generally, the objective of the study is to develop and design fuel efficient cross-draft kiln for the production of salt bed tiles.

It specifically aims to:

1. Design and fabricate fuel-efficient kiln for salt bed tiles (men and women);
2. Evaluate the performance of fuel-efficient kiln in terms of:
    - fuel consumption rate;
    - power consumption rate;
    - temperature;
    - cooking time of salt bed tiles;
    - production capacity
    - Quality of the produced salt bed tiles in terms of compressive strength. **(RTEC COMMENT)**
3. Provide production cost analysis and selling price of clay tiles per piece. **(RTEC COMMENT)**

**(8) REVIEW OF LITERATURE**

The utility model proposes an automatic control system for a natural gas tunnel kiln. The system includes a PLC main control board, multiple frequency converters, several pressure sensors, and multiple temperature sensors. The PLC main control board is connected to the natural gas tunnel kiln and is responsible for its overall control. The multiple frequency converters are linked to the PLC main control board. There are various pressure sensors, such as those for smoke discharging section, fuel gas, main combustion-supporting channel, and others, which sense different pressures within the kiln. Additionally, multiple temperature sensors are placed at various sections of the kiln. The purpose of the automatic control system is to efficiently and accurately regulate the operations of the natural gas tunnel kiln. It monitors and adjusts factors such as smoke discharging pressure, fuel gas pressure, combustion-

supporting air pressure, micro pressure differences between different kiln sections, and temperatures at various points inside the kiln. By utilizing the data from pressure and temperature sensors, the PLC main control board makes informed decisions and ensures optimal performance of the kiln throughout the firing process. This automation enhances the kiln's efficiency and precision, leading to improved product quality and energy savings. (patents.google.com/patent/CN203798151U/Automatic control system for natural gas tunnel kiln. Accessed 28 July 2023)

**(9) METHODOLOGY**

Kilns have been essential tools for firing ceramics, pottery, and other materials for centuries. It plays a crucial role in transforming raw materials into finished and durable products such as tiles, bricks, pots and other earthen products. The evolution of kiln technology from traditional wood-fired kilns to modern gas kilns has brought significant improvements in efficiency, control, and consistency.

The proposed kiln can provide an initial efficiency of 30 to 40% compare to traditional woods kilns. The machine will be fabricated by local tinsmith/fabricator in Occidental Mindoro. The performance of the developed kiln will be evaluated using actual field testing considering the heat combustion, fuel consumption, volume of salt bed tiles produce and quality of the product. The fabrication of the proposed kiln will also consider the safety and durability of the machine by selecting the best materials; the performance testing will be validated by the experts in brick production in the province.

**Phase 1- Research, Planning and fabrication**

The project initiation involves a comprehensive review of related literatures, existing kilns and construction regulations and safety protocols needed for product development. The initial phase includes a careful consideration of the design components, materials specifications and performance operations to ensure that the proposed kiln will adhere to the safety standards and the needs of the salt farmers.

A pivotal aspect of the planning stage is the careful scheduling of meetings, aligning with a predetermined timeline. These meetings facilitate a step-by-step discussion of procedures, promoting a well-organized and seamless planning process from inception through to evaluation. This strategic approach guarantees that the preparatory phase is thoroughly mapped out and executed, laying the groundwork for a secure and effectively managed construction process. The fabrication begins on the assembly of the frame using high iron steel to sustain its operating temperature. The proposed project is approximately 3mx2mx2m (Length, Width and Height); the body of machine is cover with 150mm high grade metal sheet placed on a heat insulation material that can minimize the heat loss inside the kiln chamber; next is the fabrication of slider and rack with roller. The cooking chamber is designed to have a capacity four (4) layers designed to accommodate 1920 salt bed tiles per layer the proposed kiln is designed to produce 7,680 salt bed tiles per batch of cooking. The designed temperature of the proposed kiln is $900^0$C to $1200^0$C. The cooking chamber is covered with fire bricks to provide insulation. The chimney system is designed to discharge the hot gases and fumes during the firing process and designed to control the air circulation and prevent the build-up of harmful substances inside the kiln. Further, the machine is equipped with six (6) gas burners and has connected air blower with adjustable air vent on the rear part of the gas burner to minimize the consumption of gas. The installed blower fan is controlled by a VFD or Variable Frequency Drive that adheres to the operation of the six blower fans; this will control the speed by controlling the frequency of the fan that suits to the fuel efficiency of gas kiln. The blowers are designed to open automatically after the ignition cycle of the burner. Each burner is equipped with electronic igniter to automatically fire the gas during the ignition process. The temperature gauge is installed on the top part of the gas level as additional safety features. The high-pressure gas rail line is equipped with a Rail Pressure sensor to ensure the accurate gas pressure gauge, and this is designed to shut-off the solenoid valve to reduce the risks from any explosion cause by gas leaks. This part is controlled by the PLC or Programmable Logic Controller. The machine is also protected with a manual shut of valve to ensure safety for gas leaks. A thermocouple is also installed to the upper part of the burner to detect pilot lights from gas leaks. The proposed product is also equipped with control panel placed along electronic devices intended for various purposes: the VFD/ Variable Frequency Drive, MC/ magnetic contactor, Voltmeter, UI-User Interface or LCD screen, indicator bulbs,

and push button switches.

**4.1 Phases of Activities**
The following are the different phases of activities to be carried out:

**Phase 2 – Release of Funds**
Once all the documents are submitted and approved, DOST-MIMAROPA, through PSTO-Occidental Mindoro will download/release the approved project funds to respective builder.

**Phase 3 – Training of Technical staff**
Training of the technical staff including the members (men and women) of the Team who are involved in the project will be conducted, particularly on the design, fabrication, installation, operation and maintenance, testing and evaluation of gas kiln. This activity basically will give freehand information and understanding on how the project is to be undertaken and how it is to be scaled in relation to its future application.

**Phase 4 – Fabrication and Functional Testing**
Once the design plan is completed and discussed with the Project Team, listing of the appropriate materials and equipment/tools needed will follows. The project team will then present the design to the selected CF to finally iron out everything before the fabrication process.

Regular monitoring during the fabrication will be conducted to ensure that the unit will be built as per specifications provided by the Designer. Materials to be used will be checked to ensure that they strictly conform to required specifications. In case of unavailability of the specified materials in the drawing, the Team and the Fabricator will discuss the possible alternatives fitted to the material/component requirements.

Components of the gas kiln unit will undergo functional testing and energization before the installation and upon approval of the Team. The components that will be subjected to functional testing will include the burners, temperature gauge, rail pressure sensor, blowers, VFD, MC, pilot thermocouple and other accessories.

**Phase 5 – Installation and Preliminary Testing**
After ensuring the functionality of the different parts of the Gas Kiln, the unit will be installed at Tamaco facility. Prior to the installation, the Team will visit the area to ascertain the location and to prepare the necessary pre-constructions activities.

**Phase 6 – Operation and Performance Testing and Evaluation**
The performance testing and evaluation of gas kiln will be conducted by OMSC (men and women) together with the consultants from DOST, TAMACO and other concern stakeholders. The initial test will use the pressurize air tanks to simplify the operation of gas kiln. This will trace any leaks from the gas lines and other pressurizes lines; and it will undergo a thorough inspection for some unintended faults/ asynchronization. A 5-minute interval will be implemented to assure the safety adherence to standard.

From the data gathered, the following parameters will be analyzed: (1) Fuel consumption rate (air and fuel mixture); (2) power consumption rate; (3) temperature; (4) cooking time; (5) and the quality of the produced salt bed tiles. During the actual testing of the gas kiln, data sheets will be provided to the Technical staff and salt farmers to fill-out during operation. Data to be recorded in the data sheet include: (a) fuel efficiency; (b) operating period; (c) quality of well-cooked clay tiles; and (d) others.

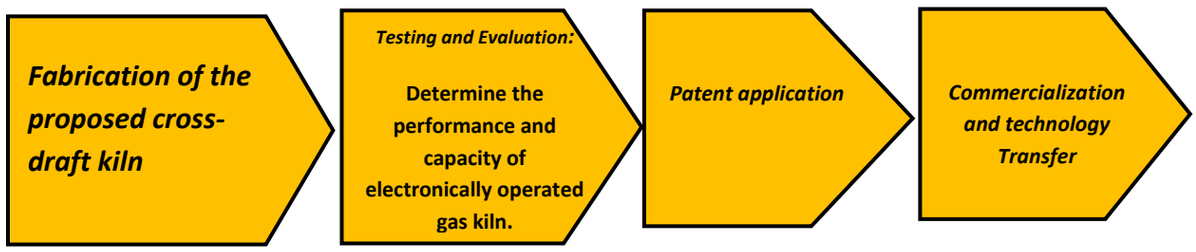
**Test the product with consultation in ITDI for material testing and evaluation. (RTEC Comments)**

**Phase 6 – Socio-Economic and Environmental Impacts Assessment**
The following information will be assessed from the project:
(1) Economics - Operating cost of the gas kiln per hour, produce cooked clay tiles per cycle, payback period, Benefit-Cost Ratio (BCR), and Return on Investment (ROI) will be analyzed based on the actual data gathered.
(2) Social Benefits - Information on the social benefits that can be derived from operating the gas kiln development through focus group discussion with the respective officials concerning on the projected ROI. This includes information on the savings derived, added income, labor opportunities, etc.
(3) Environmental Impact - This includes noise pollution, CO and CO2 emission, etc.

**Instrumentation**
The following instruments will be used during the testing of the engine-gasifier units:
1. Digital Stop Watch – This will be used to record the operating time of the proposed gas kiln.
2. Tachometer – This will be used to measure the speed of the engine shaft as well as of the generator shaft.
3. Digital Thermometer/Data Logger – This will be used to measure the internal and external temperatures and entire parts of the gas kiln.

4. Pressure Gauge - This will be used to determine the pressure required in the gas kiln.
5. Thermo-Anemometer/Data Logger - This will be used to determine the velocity of the gas passing through the gas pipe in order to account for the air or gas flow in the gas kiln.
6. Pressure Manometer – This will be used to determine the air flow of the blower fans.
7. AC Clamp Meter or Ampere Meter – This will be used to measure the current output of solar energy and the consumption of blower fans and other electronic devices connected in gas kiln.
8. Multi-Meter or Volt Meter – This will be used to measure the voltage output of the generator.
9. Hertz Meter – This will be used to measure the output cycle of the blower fan.
10. CO meter - This will be used to determine the amount of carbon dioxide emitted on the surrounding of the gas kiln during testing.
11. CO2 meter – This will be used to measure the amount of carbon dioxide emitted on the surrounding of the engine during testing.

**(10) TECHNOLOGY ROADMAP** (if applicable) (use the attached sheet)




**(11) EXPECTED OUTPUTS (6Ps)**

**Publication**

Out of this project, technical papers will prepare for paper presentation at the Philippine Salt Congress and other presentations related to Industry, Energy, and Emerging Technologies convention. Research paper will also be written and be submitted for publications in journals, or as book chapter. Technical and operation manuals of the gas kiln system will be prepared which can be used as materials for seminars/trainings to be conducted in the future.

**Patent/Intellectual Property**

Utility model will be applied for patent for the design and for the operation of the proposed design.

**Product**

Once gained acceptance, the TAMACO will be more confident to adopt the cross-draft kiln for the salt bed tile needs of the farm beds, or building new areas in salt farming. Other salt farms in Occidental Mindoro will be more engage in buying clay tiles instead of importing clay tiles from Vigan city or nearby provinces.

**People Service**

More people will benefit from it for low-cost and readily available clay tiles can be used for minor or major replacement of salt bed tiles. More skilled workers such as welders, mechanics, technical staffs of farmers' cooperatives, engineering students, researchers and developers, etc. will have the opportunity to have hands-on experience, in designing and operating a gas kiln.

**Place and Partnership**

Fabrication shops/manufacturers, other research institutions, colleges and universities, sales and distributors, etc. will have the prospect to engage in partnership with DOST-MIMAROPA.

**Policy**

Utilization of LPG or Liquified Petroleum Gas as a source of gas as an alternative to traditional wood kilns can give emphasis on R.A 8749 or the Philippine Clean Air Act of 1999. Policy will be applied on the basis of using solar energy as an alternative power source of the machine.

**(12) POTENTIAL OUTCOMES**

This project will lead to the:

a. Production of salt bed tiles needed by salt farmers;
b. Optimize the available Mindoro red clay as raw materials in the production of the salt bed tiles;
c. Provide an efficient machine that can produce volume of salt bed tiles;
d. Readily available and low cost salt bed tiles for repair and replacement needs of the farmers;
e. Long term impact on women's socioeconomic empowerment.

**(13) POTENTIAL IMPACTS (2Is)**

*Social Impact*- The technology can provide salt farmers' cooperatives access to engage in a more profitable business that can provide additional income for their members, and to have accessible locally made available clay tiles in the province.

*Economic Impact*- Cost reduction on their farming expenses especially in buying of clay tiles from other provinces (field and postharvest processing) operation. Added revenue to both local and national governments can be expected. Minimize the cost of other salt farms owners on importing clay tiles.

**(14) TARGET BENEFICIARIES**
Name: Tamaraw Salt Producers Cooperative of Occidental Mindoro (TAMACO)
Address: Pag-asa, San Jose, Occidental Mindoro
Date Organized: December 10, 2010
CDA Registration Number: 9520-04017607
Date of Registration: December 10, 2010
Current Membership: 27
Business Activities: Salt production and Aquaculture Production
Successfully-implemented projects:

**(15) SUSTAINABILITY PLAN** (if applicable)

**(16) GENDER AND DEVELOPMENT (GAD) SCORE** (refer to the attached GAD checklist)
**9.32**

**(17) LIMITATIONS OF THE PROJECT**

The project is limited to the fabrication of fuel-efficient kiln for salt bed tiles using LPG with 6 (six) Forced-Air-Burner with blower controlled by a Variable frequency drive and other related electronic devices. It can operate all genders both male and female. The machine is limited to produce an average of 7, 680 clay tiles. This will provide sufficient supply of clay tiles along the province and other nearby provinces. This also includes performance evaluation of the developed cross-draft kiln.

**(18) LIST OF RISKS AND ASSUMPTIONS RISK MANAGEMENT PLAN** (List possible risks and assumptions in attaining target outputs or objectives.) Please see DOST Form 5C Risks and Assumptions

**(19) LITERATURE CITED**
*(patents.google.com/patent/CN203798151U/Automatic control system for natural gas tunnel kiln. Accessed 28 July 2023)*

**(20) PERSONNEL REQUIREMENT**

| Position | Percent Time Devoted to the Project | Responsibilities |
|---|---|---|
| Fabricator/Supplier | 100 % | Fabrication of the Fuel-efficient gas kiln for salt bed tiles |
| Consultant | 75% | Technical aspects of the technology |
| Researchers | 75% | Data gathering and analysis |

**(21) BUDGET BY IMPLEMENTING AGENCY**

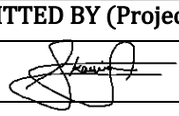
| IMPLEMENTING AGENCY | PS | MOOE | EO | Total |
|---|---|---|---|---|
| Year 1 | | | | |
| Year 2 | | | | |
| Year n | | | | |
| **TOTAL** | | | | |

**(22) OTHER ONGOING PROJECTS BEING HANDLED BY THE PROJECT LEADER:** ____ (number)

| Title of the Project | Funding Agency | Involvement in the Project |
|---|---|---|
| **none** | | |
| | | |
| | | |

**(23) OTHER SUPPORTING DOCUMENTS** (Please refer to page 2 for the additional necessary documents.)

**I hereby certify the truth of the foregoing and have no pending financial and/or technical obligations from the DOST and its attached Agencies. I further certify that the programs/projects being handled is within the prescribed number as stipulated in the DOST-GIA Guidelines. Any willful omission/false statement shall be a basis of disapproval and cancellation of the project.**

| | SUBMITTED BY (Project Leader) | ENDORSED BY (Head of the Agency) |
|---|---|---|
| Signature |  | |
| Printed Name | **KEN ANGELO M. VIVAS** | |
| Designation/Title | Project Leader | |
| Date | **May 10, 2024** | |

*Note: See guidelines/definitions at the back.*