DIN

DEPARTMENT OF INDUSTRIAL ENGINEERING

PhD Course in Mechanics and Advanced Engineering Sciences (DIMSAI)

YEARLY PHD STUDENT REPORT - AY *2016/2017*

Curriculum number *2*
Cycle *XXX*

Candidate: *Ing. Francesco Piana*
Supervisor: *Prof. Ing. Alberto Regattieri*

RESEARCH PROJECT

"Development of innovative plant design solution, sustainable and efficient for humanitarian organizations"

ALMA MATER STUDIORUM - UNIVERSITÀ DI BOLOGNA
IL PRESENTE MATERIALE È RISERVATO AL PERSONALE DELL'UNIVERSITÀ DI BOLOGNA E NON PUÒ ESSERE UTILIZZATO AI TERMINI DI LEGGE DA ALTRE PERSONE O PER FINI NON ISTITUZIONALI

Research background and questions

Research background

[..] "We are determined to **end poverty and hunger**, in all their forms and dimensions, and to ensure that all **human** beings can fulfil their **potential** in **dignity and equality** and in a **healthy** environment.
We are determined to **protect the planet** from **degradation**, including through **sustainable consumption** and **production**, sustainably managing its **natural resources** and taking urgent action on **climate change**, so that it can support the needs of the present and future generations"(United Nations, 2015).

Research Questions

"Is it possible use any equipment to **solve** problems related to **organic waste in developing regions**?"

"Is it possible produce **renewable energy** from waste in developing regions?"

"Is **renewable energy** convenient for **humanitarian camps**? Which is the best trade-off?"

United Nations, (2015) "Transforming our world: the 2030 Agenda for Sustainable Development", DOI: 10.1093/oxfordhb/9780199560103.003.0005

ALMA MATER STUDIORUM - UNIVERSITÀ DI BOLOGNA
IL PRESENTE MATERIALE È RISERVATO AL PERSONALE DELL'UNIVERSITÀ DI BOLOGNA E NON PUÒ ESSERE UTILIZZATO AI TERMINI DI LEGGE DA ALTRE PERSONE O PER FINI NON ISTITUZIONALI

Research project outline

"Development of innovative plant design solutions, sustainable and efficient for humanitarian organizations"

3 Years Project | *Themes of research*

Year 1

Waste Management

Reuse and recycle of **packaging waste** in humanitarian camps

Organic waste management by bio-digestors producing biogas as fuel

Year 2

Water purification and desalination

Purification of fresh water in developing regions

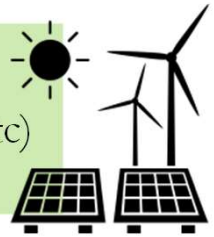
Desalination of salty water to produce **drinkable water**

Year 3

Renewable energy production

Smart-grid humanitarian **camps** (photovoltaic, wind, battery storage, etc)

Off-grid Mobile storage unit PV-BES system



IL PRESENTE MATERIALE È RISERVATO AL PERSONALE DELL'UNIVERSITÀ DI BOLOGNA E NON PUÒ ESSERE UTILIZZATO AI TERMINI DI LEGGE DA ALTRE PERSONE O PER FINI NON ISTITUZIONALI

Collaboration with WFP - UNHRD

Since 2012 the **Department of Industrial Engineering (DIN)** of Alma Mater Studiorum – University of Bologna has a **mutual partnership** with **WFP - UNHRD of Brindisi**

Application in the **humanitarian sector** of **scientific principles** to optimize the design and integration of **technologies**, **strategies**, **supply chain** processes and **infrastructures.**

Development of **education**, **methodologies** and **new approaches** for the practice of supply chain engineering and new tools for analysis, design and management of logistics and plants processes

IL PRESENTE MATERIALE È RISERVATO AL PERSONALE DELL'UNIVERSITÀ DI BOLOGNA E NON PUÒ ESSERE UTILIZZATO AI TERMINI DI LEGGE DA ALTRE PERSONE O PER FINI NON ISTITUZIONALI

Waste management

The problem of organic waste in developing regions

Problem of organic waste in rural areas and humanitarian camps

2.5 billion people in the world live **without** adequate **toilets** and **hygienic services**

Excreta-related communicable **diseases**: cholera, typhoid, dysentery, diarrhoea, hookworms, filariasis, etc.

2.2 million people each year are killed by **diarrhoea**. Most of them are **children** under five

Health of **people** depends to

- **Hygiene**
- **Sanitation**
- **Water** quality

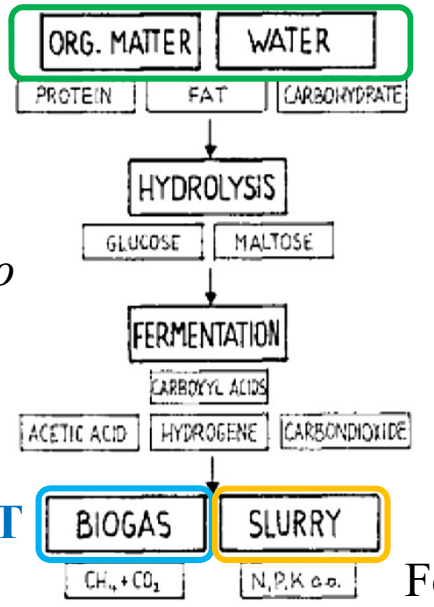
RQ: Which technologies could solve organic waste problem in developing regions?

Solution: Bio-digester

Anaerobic, hermetic container for the stocking and digestion of organic waste

INPUT

From waste to Fuel



OUTPUT

Fuel

Fertilizer

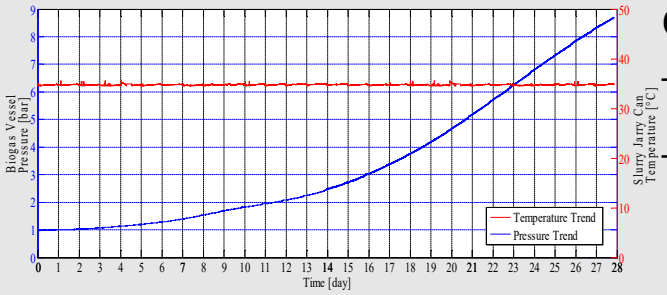
IL PRESENTE MATERIALE È RISERVATO AL PERSONALE DELL'UNIVERSITÀ DI BOLOGNA E NON PUÒ ESSERE UTILIZZATO AI TERMINI DI LEGGE DA ALTRE PERSONE O PER FINI NON ISTITUZIONALI

Waste management

The problem of organic waste in developing regions

Evaluation of Bio-digestion process

Three months of biogas production **testing** with *temperature /humidity/PH* control: Output **quality** and **quantity** of **biogas:**



0.044Nm³/kg of dry slurry

Symbol	Mass percentage [%]
CH_4	**50-70**
CO_2	30-40
H_2	5-10
N_2	1-2

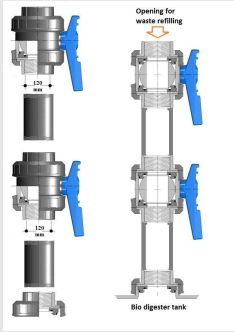
Design & Prototyping

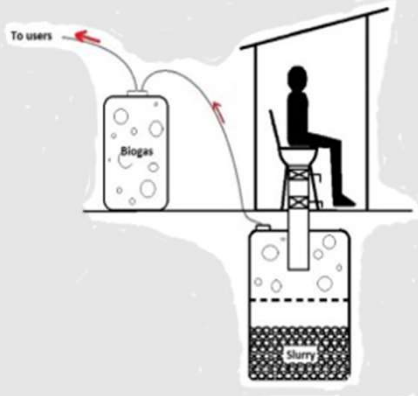
Biodigester for humanitarian camps and developing regions

Integrating with **waterless toilet**

Constrains:

- *Air/water-tight*
- *User friendly*
- *Reliable*
- *Low-cost*
- *Scalable*





Results

Biogas: a fuel rich of methane using for Cooking or heating

First prototype

ALMA MATER STUDIORUM - UNIVERSITÀ DI BOLOGNA
IL PRESENTE MATERIALE È RISERVATO AL PERSONALE DELL'UNIVERSITÀ DI BOLOGNA E NON PUÒ ESSERE UTILIZZATO AI TERMINI DI LEGGE DA ALTRE PERSONE O PER FINI NON ISTITUZIONALI

Renewable energy production

The problem of lack of cooling storage system in HL

Lack of **cooling storage** in humanitarian camps
Impossibility to **storage** perishable items like **medicines**, **drugs** and **food**
Cooling Mobile Storage Unit with PV-BES system project

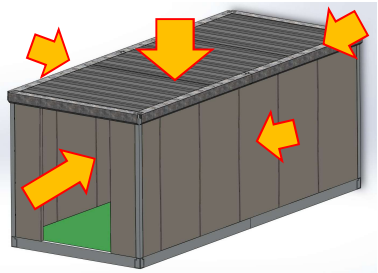
Breakdown of supply-**cold-chain** in last miles of humanitarian supply chain

Plumpy'Doz **energetic food** for HL
if **storage** at **10-25° keeps 24 months**
if storage up to **30° less** than **2 months**

Objective of the work:
Re-design a **MSU**
Method
- Analysis and study of thermal-dissipation
- Sizing and simulation of air cooler
- Design and sizing of off-gird energy system
- Economical analysis: Return On Investment Pay-back-time

RQ: Is it possible design a cooling off-gird MSU using renewable energy?

Calculation of **heat** flow into MSU by **solar irradiation** and **conduction**



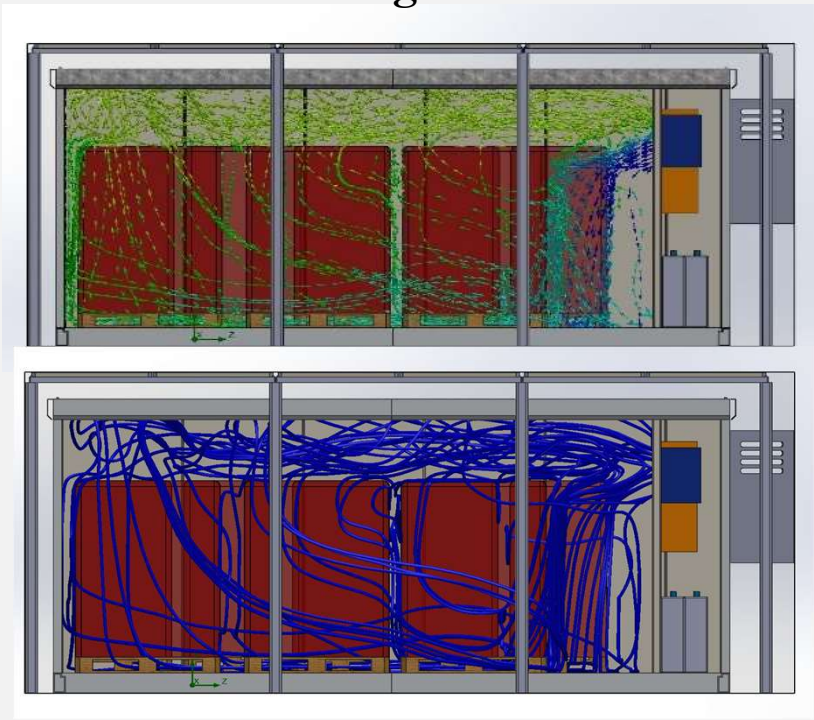
MSU Location	Qcond	Qir		
Abidjan, Côte d'Ivoire	307,78	233		
Nairobi, Kenya	282,43	242		
Theran, Iran	869,01	243		
Jakarta, indonesia	470,71	254		
Brindisi, Italy	307,78	167,47	475,25	0,48
Riyadh, Saudi Arabia	615,55	227,90	843,45	0,84
Desert, Kwait	633,65	232,49	866,15	0,87
AVERAGE [W]	498,13	228,73	726,86	0,73 [kW]

ALMA MATER STUDIORUM - UNIVERSITÀ DI BOLOGNA
IL PRESENTE MATERIALE È RISERVATO AL PERSONALE DELL'UNIVERSITÀ DI BOLOGNA E NON PUÒ ESSERE UTILIZZATO AI TERMINI DI LEGGE DA ALTRE PERSONE O PER FINI NON ISTITUZIONALI

Renewable energy production

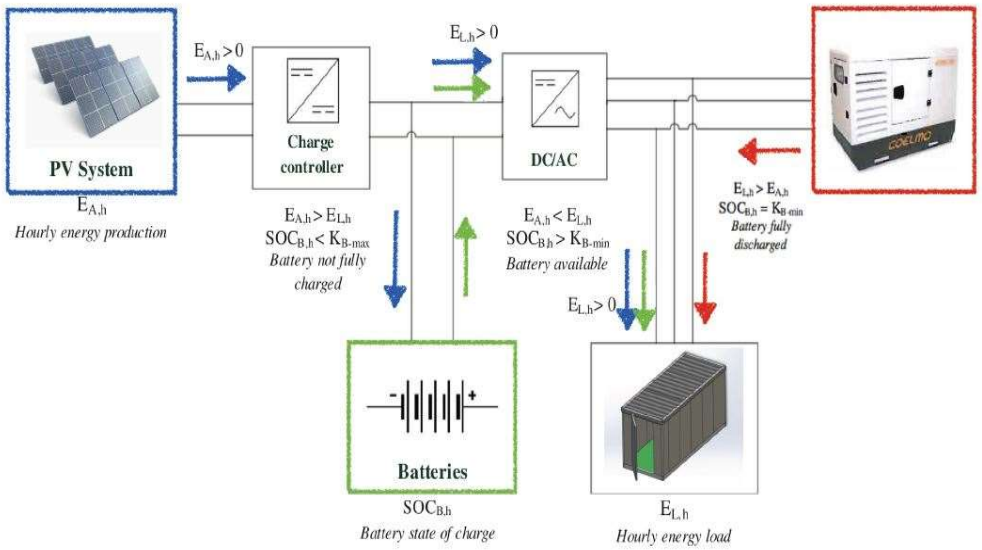
The problem of lack of cooling storage system in HL

Air cooler sizing and simulation



Design and sizing of off-gird energy system

Photovoltaic system, **Battery** energy storage and Diesel **generator** as back-up



Results:

Re-design of **MSU** with **Cooling system** with **Photovoltaic** (PV) and **Battery**-Energy-**Storage** (BES) system with Generator as back-up

ALMA MATER STUDIORUM - UNIVERSITÀ DI BOLOGNA
IL PRESENTE MATERIALE È RISERVATO AL PERSONALE DELL'UNIVERSITÀ DI BOLOGNA E NON PUÒ ESSERE UTILIZZATO AI TERMINI DI LEGGE DA ALTRE PERSONE O PER FINI NON ISTITUZIONALI

Results & knowledge dissemination

Results

Innovative **packaging prototypes** using suppling materials for humanitarian agencies

Waterless toilet integrating **bio-digester** (prototype) for the bio-gas production

Reverse Osmosis analysis and review for use sea-salt water in humanitarian contest

Cooling, off-grid with PV-BES-GEN system, **Mobile Storage Unit** (prototype)

Optimization model of **renewable energy** consumption of a **humanitarian camp**

Scientific Publications

L. Botti, A. Casto, A. Regattieri, F. Piana, (2017) "*Tackling the water scarcity problem in rural areas: guidelines and best design practices*", XXII Summer School Francesco Turco – Industrial System Engineering. AIDI conference Palermo September

A. Regattieri, F. Piana, M. Bortolini, M. Gamberi, E. Ferrari, (2016), "*Innovative portable solar cooker using the packaging waste of humanitarian supplies*", Renewable and Sustainable Energy Reviews, Volume 57, Pages 319-326. DOI: 10.1016/j.rser.2015.12.199

A. Regattieri, M. Bortolini, E. Ferrari, M. Gamberi, F. Piana, (2016), "*Biogas micro-production from organic waste. A smart system for developing regions*", Under review in Renewable & Sustainable Energy Reviews

A. Regattieri, F. Piana, R. Gamberini, F. Lolli, (2016), "*A refugee camp: reference framework and taxonomy for the technical requirements*", Under review in International Journal of Engineering Business Management

A. Regattieri, F. Piana, M. Gamberi, M. Bortolini, E. Ferrari, F. Massanova, (2015), "*Biogas production from organic waste: design and field-test of a pilot plant for developing regions*", The 23rd International Conference on Production Research, Manila Philippines August 2015.

A. Regattieri, M. Gamberi, G. Santarelli, F. Piana, (2015), "*Classification of technical requirements and the problem of waste management in a refugee camp*", Humanitarian logistics and sustainability, in the Springer LNL series. Pages 169-192. Ed: M. Klumpp, S. de Leeuw, A. Regattieri, R. de Souza, Springer international Publishing, ISBN 9783319154541. DOI: 10.1007/978-3-319-15455-8_10

IL PRESENTE MATERIALE È RISERVATO AL PERSONALE DELL'UNIVERSITÀ DI BOLOGNA E NON PUÒ ESSERE UTILIZZATO AI TERMINI DI LEGGE DA ALTRE PERSONE O PER FINI NON ISTITUZIONALI

ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

Eng. Francesco Piana

DIN – Department of Industrial Engineering

francesco.piana2@unibo.it

www.unibo.it

IL PRESENTE MATERIALE È RISERVATO AL PERSONALE DELL'UNIVERSITÀ DI BOLOGNA E NON PUÒ ESSERE UTILIZZATO AI TERMINI DI LEGGE DA ALTRE PERSONE O PER FINI NON ISTITUZIONALI