FORMAT FOR PROPOSAL

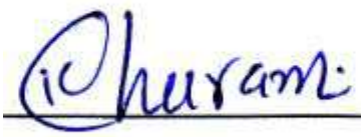
PEC ANNUAL AWARD OF FINAL YEAR DESIGN PROJECTS (FYDP)

a.	Name of University/Institution	Mirpur University of Science and Technology (MUST) / Department of Mechanical Engineering
b.	Campus	Mirpur, Azad Kashmir
c.	Title of Project *(project proposal to be attached)*	Design, development and experimental analysis of a waste heat recovery system for the surface of a rotary cement kiln
d.	Discipline/ Group	1. Mechanical / Group 2 2. Energy / Group 5
e.	Name of student (s)	(1) Shahbaz Sharif (2) Muhammad Hasnain (3) Muhammad Ehtisham
f.	Name of Supervisor/Faculty Members	Supervisor: Engr. Dr. Khuram Pervez Amber Co-Supervisor: Engr. Nasir Iqbal
g.	Salient features/ Abstract of Project proposals (Demonstrating Industrial/ Societal problems)	Cement industry in Pakistan is a well-established industry and is playing a vital role in strengthening Pakistan's economy. It represents 1.4% of Pakistan's GDP. Often kiln is considered as a heart of the Cement industry which is the very important component in the production of the cement and consumes most of the energy in the production process. A typical cement kiln has an efficiency of only 49% where about 51% of energy is wasted in the form of flue gases and from the kiln's surface. A number of cement plants in Pakistan including Gharibwal Cement Ltd have had installed waste heat recovery systems (HRSs) in order to enhance the overall efficiency of their plants. These HRSs capture waste heat from the kiln's flue gases and generate high-pressure steam which is then used to run a steam turbine to generate electricity. However, a limited attention has been paid to 15% heat loss from the kiln's surface, i.e. 4% due to convection and 11% due to radiation. Therefore, heat recovery from rotary kiln's surface is an alternative promising method for energy conservation in cement industry. This Final Year Design project proposal is being submitted to PEC in coordination with Gharibwal Cement Ltd (GCL). GCL is located in district

		Chakwal and has a daily cement production capacity of 6,700 tons. Recently GCL has installed an HRS which captures heat from its kiln's flue gases and generates 18 MW electricity through a steam turbine. However, like other cement plants in Pakistan, heat loss from GCL's kiln surface has yet to be addressed. Central Control Room (CCR) of GCL is about 15m away from the kiln and has an installed cooling load of 40TR (140kW) with a temperature set point of 25°C. This load runs 24/7 for the whole year. At current this cooling load is being met by vapor compression air conditioners which would consume 1,226,400kWh per year resulting in an annual electricity bill of nearly 54 Million Pakistani Rupees @ 44 PKR/kWh (US$245,280). Capturing the waste heat from the kiln surface through an HRS, hot water could be produced which could then be fed into a properly sized Absorption Cooling System (ACS) to generate cooling to meet the cooling requirements of CCR. This way, a considerable proportion of the CCR's current cooling load could be offset. A preliminary analysis was performed which shows that such scheme would result in a financial savings of 13.5M PKR per annum whereas the payback period will be less than two years. A presentation of this potential opportunity was delivered to higher management of GCL 0n 13 March 2022 at their plant site where the management appreciated this idea. In the meeting with the Executive Director Operations GCL, different aspects of this opportunity were discussed. The Executive Director Operations informed that kiln is highly sensitive part of the cement plant and under no conditions, its operation should be disturbed and the proposed WHRS must be designed keeping this fact in mind. The Executive Director Operations GCL ensured to support this project and appointed Mr. Mudassar Farooq (Senior Manager) as the focal person from GCL side for this project. This project aims to capture the waste heat from the rotary kiln surface through a new design of Waste Heat Recovery System (WHRS). Water will be used as working fluid inside the tubes of WHRS. To maximize the heat absorbing surface area, it is intended to use an insulation around the tubes of WHRS. Precisely, in the first phase of this project, we have collected the data for GCL kiln surface temperature and other relevant information has already been collected through the site visits. Surface temperature were measured during different periods of the year using an infrared laser thermometer. In the

		second phase of the project, analytical and numerical analysis was performed to estimate net heat loss from the kiln surface. In the third phase, a new type of heat exchanger was designed and locally manufactured. In the fourth phase, the designed and optimized WHRS will be now experimentally tested for its effectiveness. Experimental measurements will be carried out to investigate the heat transfer characteristics of this heat recovery exchanger, WHRS. The temperature at different points of the WHRS will be measured and recorded. In the final phase, i.e. the Seventh phase, economic evaluation of an Absorption Cooling System (ACS) for the GCL CCR will be undertaken based on heat recovery from the proposed WHRS.
h.	Expected Outcome of Project Proposal	This project will bring improvement and innovation within the local cement industry of Pakistan by the introduction of a new thermally optimized WHRS to capture the waste heat from the rotary kiln surface. This innovation will be based on research and development. The research results will then be shared with the local and international community through international conference and a high impact factor journal publication. The adoption of innovative technology will improve the overall efficiency of cement plants and will save a significant amount of electricity being used for the cooling purpose. Further, it will reduce the burden on the national grid and will result in higher economic and environmental savings. These technological advancements and product innovation in WHRS manufacturing will facilitate the technology-oriented human-resource development in WHRS manufacturing industry. The followings are the key expected impact level results of the proposed project: 1. Improved efficiency of cement plants through the product innovation 2. Reduced electricity consumption for the cooling purpose 3. Reduced coal import 4. Reduced environmental impact 5. Export potential of new design of WHRS for the kiln surface 6. Provision of new business opportunity 7.Development of high-tech testing facility

i.	Estimate for Project proposal	**01 Million (Approximate)**
j.	Has the proposed project been included in any National or International Competition (Yes/No) *(If Yes, then details of getting any prize or certificate)*	**No**
k.	Innovation/ development/ improvement in the existing procedure/ product/ process as outcome of the project	Main Innovation will be a new and thermally optimized design of a waste heat recovery system (WHRS) for capturing the waste heat from the rotary kiln surface of a cement plant. This will be a moveable type of WHRS in which steam will be produced using the waste heat from the kiln's surface. This steam will then be fed into an absorption cooling system which will generate cooling. This will not only increase the overall efficiency of the cement plant but will result in various other social, financial and environmental benefits.



Signature with Stamp

Name of HoD: **Engr. Dr. Khuram Pervez Amber**

PAKISTAN ENGINEERING COUNCIL

Attaturk Avenue (East) G-5/2, P.O. Box: 1296, Islamabad,
(Pakistan)

PEC ANNUAL AWARD FOR BEST FYDP FOR THE YEAR 2022-23

PROTOTYPE/PRODUCT DEVELOPMENT PROPOSAL

COVER SHEET FOR PROPOSAL

TITLE OF PROPOSED FINAL YEAR DESIGN PROJECT

Design, development and experimental analysis of a waste heat recovery system for the surface of a rotary cement kiln

CLASSIFICATION/NAME OF PRODUCT/PROCESS/SERVICE TO BE CREATED

Heat Transfer / Waste Heat Recovery System / Cement Factory Kiln / Heat Exchange

Supervisor

Engr. Dr. Khuram Pervez Amber (CEng, MEI, PE, AFHEA)

Associate Professor

Department of Mechanical Engineering

Mirpur University of Science and Technology (MUST)

Mirpur, AJK, Pakistan

PROJECT DETAILS

1. PROJECT SUMMARY

Describe the proposed prototype and any research required using (about 250) words. Attach sketch/diagrams/photo, if needed, to illustrate your concept.

Cement production is one of the most energy-intensive industrial processes and this industry plays a vital role in Pakistan's economy. Therefore, improving the energy efficiency has become one of the key issues in the cement industry. A huge amount of energy is wasted from the kiln surface in the form of radiation and convection. This project aims to capture the waste heat from the high-temperature zone of Gharibwal Cement Ltd (GCL)'s kiln surface through the installation of a newly designed and thermally optimized Waste Heat Recovery System (WHRS). For this purpose, a scale down model of rotary cement kiln has been manufactured in the workshop of Mechanical Engineering Department. For capturing waste heat from the rotary cement kiln, a Waste Heat Recovery System (WHRS) will be designed and its thermal simulation will be performed under different boundary conditions using ANSYS software at the Heat and Mass Transfer Laboratory of the Mechanical Engineering Department of Mirpur University of Science and Technology. After finding a thermally optimized design of WHRS, the WHRS will be manufacture/assembled at the Mechanical Workshop of Department of Mechanical Engineering, MUST. It will then be installed on the scale down model of rotary cement kiln and experiments will be performed for its evaluation.

Validation of thermal simulation results will be performed by varying distance between the kiln surface and WHRS. Secondly, the effect of different flow rates on the total heat transfer will be investigated by varying the flow rate. After finding the optimum distance from the kiln surface and the optimum flow rate, performance of WHRS. As a second case, the performance of this WHRS will also be analyzed by forced convection using fans on the back surface of WHRS. Knowledge of Heat Transfer (Free and Forced Convection Heat Transfer + Radiation Heat Transfer) and performance analysis methods of heat exchangers, i.e. Logarithmic Mean Temperature Difference (LMTD) and Number of Transfer Units (NTU) will be applied during design and testing phases. In the third case, it is intended to use Phase Change Material (PCM) around the water tubes in order to capture the maximum amount of radiation heat from the kiln surface. Fins will be installed on the surface of tubes of the WHRS to increase the surface area to further enhance the heat transfer rate. Using measured values of the outlet temperature of water, the technical and economic feasibility of an optimized size of Absorption Cooling System (ACS) will be investigated. An optimized size of ACS will be calculated which should offer higher economic benefits with lower payback period.

Fig. 1 shows the schematic diagram of proposed WHRS for the rotary cement kiln surface

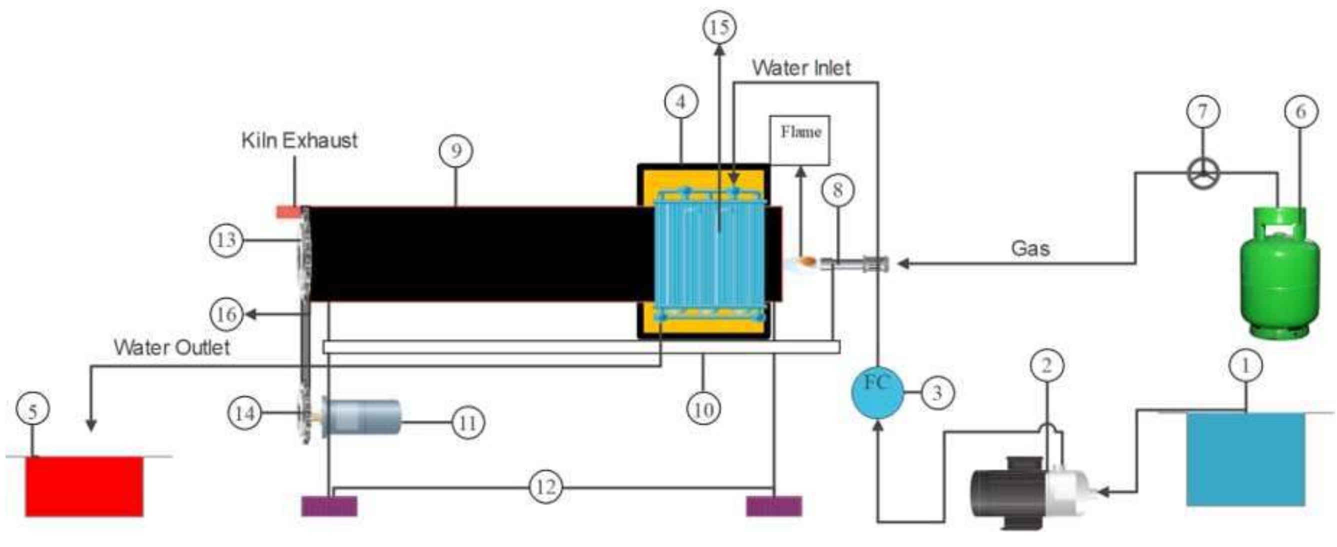


Fig. 1 Schematic diagram of proposed WHRS for the rotary cement kiln surface

Sr No.	Componenents
01	Cold Water Tank
02	Pump
03	Water Flow Valve
04	Insulation Box
05	Hot Water Tank
06	Gas Cylinder
07	Gas Flow Controller
08	Gas Burner

Sr No.	Componenents
9	Kiln
10	Stand
11	DC Motor
12	Frame Supports
13	Upper Sprocket
14	Lower Sprocket
15	WHR System
16	Chain Drive

The proposed WHRS is of a tubular heat exchanger type having fins on its tubes. Water flows through the copper tubes with the help of a pump. Performance of this model will be analyzed under different conditions. Preliminary results obtained through these experiments suggest that there is a strong potential for the proposed solution for GCL. As a part of this FYDP, preliminary economic analysis for an ACS shows that such system will have an annual financial savings of 113.5M PKR with a payback period of fewer than three years. These results were presented to GCL's higher management and were discussed with Executive Director Operations GCL in detail. Executive Director Operations confirmed that GCL will support such research-oriented FYD project.

2. PROPOSED GOALS/OBJECTIVES (please identify quantifiable goals)

Please clearly identify the output in the form of a **product or process, need or relationship to industry** and also identify other end-users of your output/product.

GOALS/OBJECTIVES (please quantify your objectives in case of Applied research)

1. To design a thermally optimized Waste Heat Recovery System (WHRS) for capturing radiation and convection heat from a rotary cement kiln surface.
2. To fabricate a scale down model of rotary cement kiln
3. To fabricate a thermally optimized WHRS in the mechanical workshop of GCL
4. Installation and testing of the performance of the proposed WHRS under different conditions
5. Sizing of an optimized Absorption Cooling System (ACS) based on the data collected from the WHRS using EES software.

6. Economic Analysis preferably Life Cycle Analysis (LCA) of optimized ACS

7. To undertake a sensitivity analysis considering future variation in operating and maintenance costs

3. INTRODUCTION (not to exceed one page)

Cement production is one of the most energy-intensive industrial processes, where some well-equipped plants still consume about 3 to 4 GJ to produce only one ton of cement. The cement industry consumes a larger proportion of energy compare to other industrial sectors. Therefore, improving the energy efficiency has become one of the key issues in the cement industry [1-3]. Cement industry plays a vital role in Pakistan's economy. It is a well-established industry in Pakistan which accounts for 5.5% of Pakistan's total industrial production and represents 1.4% of GDP and contributing 30 billion Pakistani Rupee to Pakistan's economy [4]. There are 24 cement plants in Pakistan at current [5]. A major proportion of energy is consumed in the rotary kiln of the cement plant where the fuel is burned to dry the clinker. Rotary kiln is a long horizontal, low speed rotating cylinder tilted at some angle, 4-5°. Raw material is fed from higher-end whereas burner is on the other lower end. Due to the rotation of the kiln and the tilt angle, the raw material keeps moving towards the burner and is converted into cement stones called clinker. Kiln's inner side has special refectory lining with low thermal conductivity for lower heat transfer rate to surrounding. The outer layer of kiln is made of steel. Temperature in the burning zone could be as high as 1400°C whereas in low temperature zone, temperature is in the range of 700-800°C. Huge amount of heat is lost from the kiln surface in the form of mainly radiation and some part of it in the form of convection. Surface temperature of kiln in the burning zone is nearly 320-350°C. Utilizing this waste heat for some useful purpose could increase the overall efficiency of the cement plant.

This research proposal aims to capture this waste heat from the rotary kiln surface through a new design of Waste Heat Recovery System (WHRS). Water will be used as working fluid inside the tubes of WHRS. To maximize the heat absorbing surface area, it is intended to use a suitable Phase Change Material (PCM) outside the tubes of WHRS. Precisely, in the first phase of this project, we will collect the data for GCL kiln surface temperature and surrounding air temperature at different distances from the kiln surface plus other relevant information will be collected through the site visits. The surface temperature will be measured during different periods of the year using an infrared laser thermometer. In the second phase of the project, a scale down model of the rotary cement kiln will be manufactured. In the third phase, numerical modelling using ANSYS software will be performed to estimate net heat loss from the kiln surface. In the fourth phase, a new type of heat exchanger will be designed analytically with optimum flow rate and optimum distance from the kiln. In the fifth phase the designed and optimized WHRS will be manufactured in the Mechanical Workshop. The sixth phase will include the installation of the WHRS at the optimum distance with an optimum flow rate of circulating fluid. WHRS will be tested in this phase for a minimum period of three months. Experimental measurements will be carried out to investigate the heat transfer characteristics of this heat recovery exchanger, WHRS. Temperature at different points of the WHRS will be measured and recorded. Through this the results will be transformed for the GCL rotary cement kiln. In the seventh phase, economic evaluation of an Absorption Cooling System (ACS) for the GCL CCR will be undertaken based on heat recovery from the proposed WHRS. In the final phase, i.e. eighth phase, results will be shared via an international conference and through publication in high impact factor journal.

Through the proposed project, we would be able to increase the overall efficiency of the GCL cement plant. Secondly, we would be able to introduce this concept to other cement plants. Thirdly, we would be able to reduce the burden on the national electricity grid. Overall, the final product will be a Heat Exchanger for capturing IR heat loss from the kiln surface. Further, it is anticipated that this new idea would open new avenues of export.

4A. BACKGROUND AND METHODOLOGY OF THE PROPOSED RESEARCH (Not to exceed two pages)

Background

Cement production is one of the most energy-intensive industrial processes, where some well-equipped plants still consume about 3 to 4 GJ to produce only one ton of cement. The cement industry has consumed a larger proportion of energy compare to other industrial sectors. Therefore, improving the energy efficiency has become one of the key issues in the cement industry [1-3]. Cement industry plays a vital role in Pakistan's economy. The cement industry is a well-established industry in Pakistan which accounts for 5.5% of Pakistan's total industrial production and represents 1.4% of GDP and contributing 30 billion Pakistani Rupee to Pakistan's economy [4].There are 24 cement plants in Pakistan at current with a total operational capacity of 46.971 Mtons of Cement [5].

A major proportion of energy is consumed in the rotary kiln of the cement plant where the fuel is burned to dry the clinker. Rotary kiln is a long horizontal, low speed rotating cylinder tilted at some angle, 2-5°. The efficiency of Rotary kiln is about 48.7 % and 51% heat is being lost. Out of 51% waste heat, 25% heat is lost from stacks of clinker cooler and raw mill electrostatic precipitation (flue gases), 15% from the surface of the rotary kiln and 11% of waste heat is utilized as a tertiary air in the preheater. Most of the cement industries have had installed WHRS to capture the waste heat from the flue gases to generate electricity. Fig. 2 shows the cement plants which have installed HRS along with their electricity generation capacities.

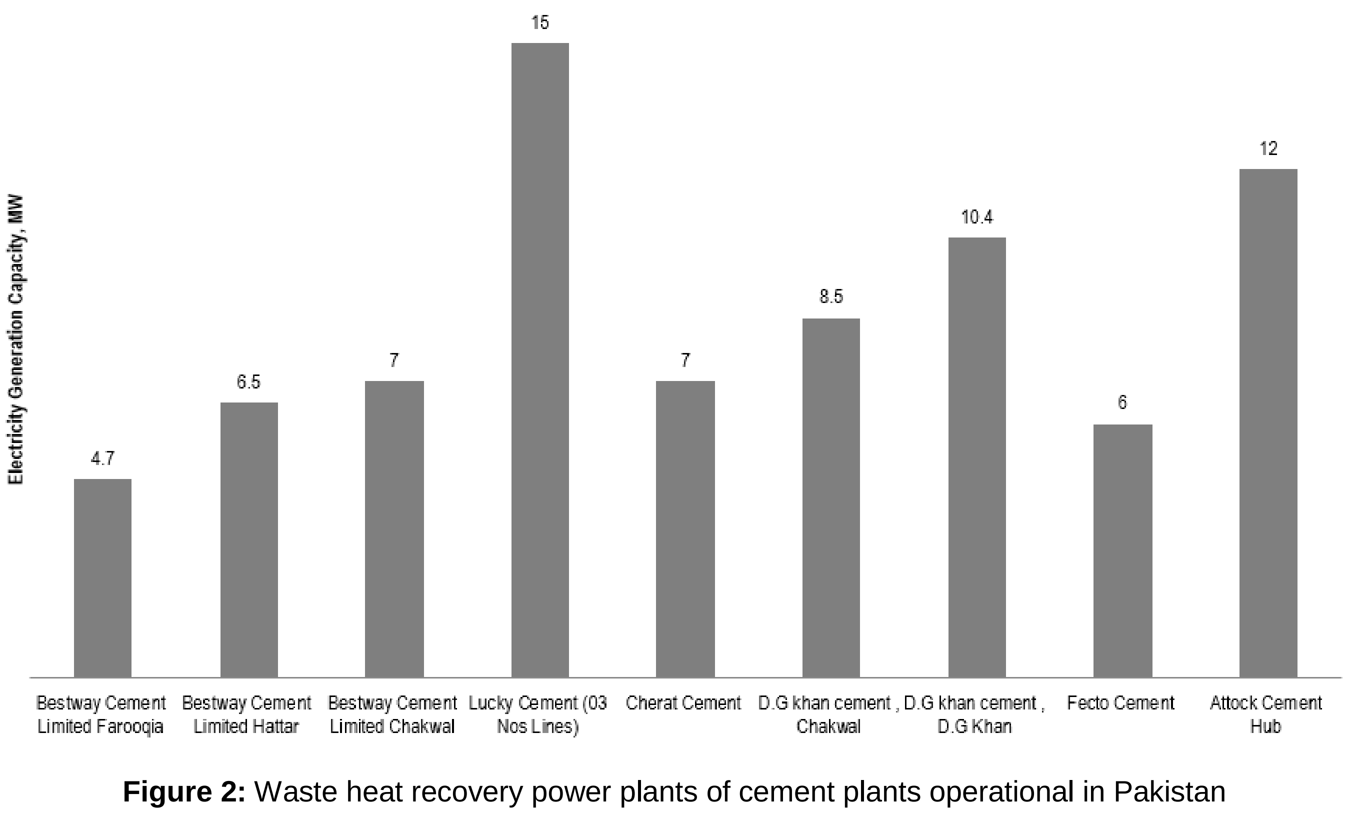


Figure 2: Waste heat recovery power plants of cement plants operational in Pakistan

It is apparent that Lucky Cement and Attock Cement WHRs have higher electricity generating capacities compared to other plants.

Heat loss from Kiln's surface is also significant and accounts for 15% of total energy. For a typical cement plant having a capacity of 600 ton/day-clinker, this accounts for 4 MW of energy that could be recovered from the surface of kiln [6-7]. The raw material is fed from higher-end whereas burner is on the lower end of the kiln. Due to the rotation of the kiln and its tilt angle, the raw material keeps moving towards the burner and is converted into cement stones called clinker. Kiln's inner side has special refectory lining with low thermal conductivity for lower heat transfer rate to the surrounding. The outer layer of the kiln is made of steel. The temperature in the burning zone could be as high as 1400°C whereas in low-temperature zone, the temperature is in the range of 700-800°C. A significant amount of energy (15%) is lost from the kiln surface in the form of radiation (11%) mainly and 4% of it in the form of convection. The surface temperature of the kiln in the burning zone is nearly 320-350°C. Utilizing this waste heat for some useful purpose could increase the overall efficiency of the cement plant.

To investigate the potential of recovering this heat loss from kiln surface, a scale down model of kiln and WHRS has already been fabricated and tested under varying operating conditions in the HMT laboratory of Mechanical Engineering Department of MUST. Results obtained through these experiments suggest that there is a strong potential for the proposed solution for GCL. As a part of this FYDP, preliminary economic analysis for an ACS shows that such system will have an annual financial savings of 13.5M PKR with a payback period of less than three years. These results were presented to GCL's higher management and opportunity were discussed with Executive Director Operations GCL in detail. Executive Director Operations confirmed that GCL will support such research-oriented FYD project.

This project proposal aims to capture this waste heat from the Gharibwal Cement Ltd (GCL) cement plant's rotary kiln surface through a new design of Waste Heat Recovery System (WHRS) and further aims to convert this waste kiln surface heat into cooling for the CCR through an Absorption Cooling System (ACS). An ACS requires hot water to generate chilled water which could be used for space cooling via an Air Handling Unit (AHU).

For this purpose, a meeting was arranged with the Director Operations at GCL site in Chakwal, Pakistan. During this meeting, the scope of the project was discussed under PEC's call for FYDP proposals. All necessary aspects of the project were discussed with the higher management team of GCL.
The Director Operations GCL informed that kiln is a highly sensitive component of the cement plant and its surface temperature is being monitored via an IR scanner on real-time basis. Because of this fact, it will not be possible to cover the kiln's whole circumferential surface by the proposed WHRS. Therefore, it was decided that the WHRS will be designed for that half circumferential part of the kiln surface which is not being monitored by the IR scanner. Later, visit to GCL's CCR helped us in understanding the kiln's surface temperature in different zones of the kiln. It was witnessed that surface temperature is higher in the burning zone (i.e. in the range of 300-350°C) and is lower on the other end of the kiln. It was decided that once the project starts, GCL will provide historical data for its kiln's surface temperature. The following Kiln's data shown in Table 1 was provided by GCL.

Table 1 Technical Specifications of GCL kiln

	Parameter	**Value**
1	Diameter	5m
2	Length	72m

3	Kiln tilt angle	2°
4	Rotation Speed	3.96 rpm
5	Avg. monthly running hours of kiln	600 hours / month

For the purpose of economic evaluation of Absorption Cooling System (ACS), GCL officials informed that CCR has a cooling load of 40TR and its set point for CCR is 25°C. Further, it was informed that approximate distance between GCL kiln and its CCR is 15 meters. This information was necessary for the economic evaluation of ACS for GCL's CCR.

Proposed Methodology

A scale down model of rotary cement kiln will be manufactured whereas WHRS will be designed and installed around this kiln surface. Through the experimentation, data will be collected and calculations will be made for GCL kiln. Water will be used as working fluid inside the tubes of proposed heat recovery WHRS. To maximize the heat absorbing surface area, it is intended to use a suitable Phase Change Material (PCM) around the tubes of WHRS. Precisely, in the first phase of this project, we will collect the data for GCL kiln surface temperature and surrounding air temperature at different distances from the kiln surface plus other relevant information will be collected through the site visits. The surface temperature will be measured during different periods of the year using an infrared laser thermometer. In the second phase of the project, a scale down model of the rotary cement kiln will be manufactured. In the third phase, numerical modelling using ANSYS software will be performed to estimate net heat loss from the kiln surface. In the fourth phase, a new type of heat exchanger will be designed analytically with optimum flow rate and optimum distance from the kiln. In the fifth phase the designed and optimized WHRS will be manufactured in the Mechanical Workshop. The sixth phase will include the installation of the WHRS at the optimum distance with an optimum flow rate of circulating fluid. WHRS will be tested in this phase for a minimum period of three months. Experimental measurements will be carried out to investigate the heat transfer characteristics of this heat recovery exchanger, WHRS. Temperature at different points of the WHRS will be measured and recorded. Through this the results will be transformed for the GCL rotary cement kiln. In the seventh phase, economic evaluation of an Absorption Cooling System (ACS) for the GCL CCR will be undertaken based on heat recovery from the proposed WHRS. In the final phase, i.e. eighth phase, results will be shared via an international conference and through publication in high impact factor journal.

Through the proposed project, we would be able to increase the overall efficiency of the GCL cement plant. Secondly we would be able to introduce this new concept in other cement plants. Thirdly we would be able to reduce the burden on national electricity grid by shifting total or a proportion of cooling load of CCR on the Absorption Cooling System (ACS). Overall, the final product will be a Heat Exchanger for capturing IR and convective heat loss from the kiln surface. Further it is anticipated that this new idea would open new avenues of export and will contribute towards our national economy.

4B. RESEARCH PLAN: SCHEDULE/PHASING (Preferably with a time-chart not to exceed one page**)**

	Phase-1	Phase-2	Phase-3	Phase-4	Phase-5	Phase-6	Phase-7	Phase-8
Month	Literature Review and Data Collection	Fabrication of a scale down model of rotary cement kiln	Numerical analysis of heat loss from the kiln's surface	Design of WHRS	Fabrication of WHRS	Experimentation	Economic Evaluation of ACR	Results sharing via national/international conference
Oct-22	■							
Nov-22	■							
Dec-22		■						
Jan-23		■	■					
Feb-23				■				
Mar-23					■			
Apr-23						■		
May-23						■		
Jun-23						■		
Jul-23							■	
Aug-23							■	
Sep-23								■

4C. REFERENCES

[1]. Yin, Q., Chen, Q., Du, W.J., Ji, X.L. and Cheng, L., 2016. Design requirements and performance optimization of waste heat recovery systems for rotary kilns. International Journal of Heat and Mass Transfer, 93, pp.1-8.

[2]. Yin, Q., Du, W.J., Ji, X.L. and Cheng, L., 2017. Optimization design based on the thermal resistance analyses of heat recovery systems for rotary kilns. Applied Thermal Engineering, 112, pp.1260-1270.

[3]. Yin, Q., Du, W.J. and Cheng, L., 2017. Optimization design of heat recovery systems on rotary kilns using genetic algorithms. Applied Energy, 202, pp.153-168.

[4]. Ghulam, Y. and Jaffry, S., 2015. Efficiency and productivity of the cement industry: Pakistani experience of deregulation and privatization. Omega, 54, pp.101-115.

[5]. All Pakistan Cement Manufacturers Association (APCMA), Installed Capacity, [Online Available at] http://www.apcma.com/data_productioncapacity.html, Accessed on [October 30, 2017]

[6]. Khan, S.W.A., Technical, financial and environmental assessment of an absorption cooling system using the waste heat from rotary cement kiln shell, Unpublished MS Thesis, Mirpur University of Science and Technology, October 2017

[7] Shaukat, A., Potential Assessment of Waste Heat Recovery from Rotary Kiln Shell, Unpublished MS Thesis, , University of Engineering and Technology Taxila, January 2016

5. IMPACT

This project will bring improvement and innovation within the local cement industry of Pakistan by the introduction of a new thermally optimized WHRS to capture the waste heat from the rotary kiln surface. This innovation will be based on research and development. The research results will then be shared with the local and international community through international conference and a high impact factor journal publication. The adoption of innovative technology will improve the overall efficiency of cement plants and will save a significant amount of electricity being used for the cooling purpose. Further, it will reduce the burden on the national grid and will result in higher economic and environmental savings. These technological advancements and product innovation in WHRS manufacturing will facilitate the technology-oriented human-resource development in WHRS manufacturing industry.

The followings are the key expected impact level results of the proposed project:

1. Improved efficiency of cement plants through the product innovation

2. Reduced electricity consumption for the cooling purpose
3. Reduced environmental impact
4. Export potential of new design of WHRS for the kiln surface
5. Provision of new business opportunity
6. Development of high-tech testing facility

6. Sustainable Development Goals (SDG's) (How and which of the SDG's will be addressed in this study? Justify how the proposed research will contribute to achieve SDG's of Pakistan. For details on SDG's /s please visit:)

- http://undocs.org/A/68/970
- http://www.un.org/sustainabledevelopment/sustainable-development-goals
- http://www.slideshare.net/derekschwabe/the-17-proposed-sustainable-development-goals

The proposed project is directly aligned with SDG-7 "Affordable and clean energy", SDG-8 "Decent work and economic growth", SDG-9 "Industry, innovation, infrastructure" and SDG-12 "Responsible consumption, production" As proposed through this project, the innovation will be brought in the cement industry through introduction of a new efficient Waste Heat Recovery System (WHRS) for capturing heat from the Cement Industry's rotary kiln surface. This innovation will excel the smart WHRS production in the country thus making it more competitive and export oriented in international market. Following are some of the key highlights in relation to aligned SDGs:

- Ensure access to affordable, reliable, sustainable and modern energy for all;
- Promote inclusive and sustainable economic growth, employment and decent work for all;
- Build resilient infrastructure, promote sustainable industrialization and foster innovation; and,
- Ensure sustainable consumption and production patterns.

7. PROJECT PARTNERS (information on Industry)

Please give a brief introduction of the collaborating industry, especially information on turnover, import/export profile, stock exchange listing etc. Please indicate the portion of the proposed research program to be carried out at the Partners organization. Also state that how and where the Partner's budgetary contribution will be utilized.

Gharibwal Cement Ltd (GCL) – Chakwal is a cement manufacturer since 1960. Its brand "PAIDAR CEMENT" is known for its durability and strength with proven history in construction of Mangla Dam, Qadirabad Barrage and Rasul Barrage. Current cement production capacity of GCL plant is 6,700 tons / day. The plant is composed of about 60% Chinese components and 40% European components that have already been proved and tested worldwide including Pakistan. Specialized equipment and parts like raw mill, coal mill, electrical instruments, packing plant are Europe origin. We also have in-house power generation plant of 38MW.

GCL has quarry of prime limestone and shale, main ingredient of cement, having reserves sufficient for 200 years. A 3.5 Km long state-of-art conveyor belt can transport 1200 ton per hour of raw materials from quarry hill down to pre-blending yard. This down-hill conveyor belt also generates electricity up to 1.1 MW (approx.) which makes it self-sufficient in energy consumption during its operation.

Waste Heat Recovery (WHR) Plant is also under test-phase which will generate electricity up to 12MW from the waste hot gases of the process and 8MW from coal-fired system. GCL has contracted with CITIC China for installation of another line of 8000 ton per day clinker production capacity along with additional waste heat recovery plant which will increase the clinker production capacity to 14700 ton per day [Source: www.gharibwalcement.com].

The Company’s shares are quoted on Pakistan Stock Exchange (https://www.psx.com.pk) with company symbol “GWLC”.
As per Annual Report of the Company for the year ended June 30, 2016:
Authorized shares capital = 470,000,000 Ordinary Shares of Rs. 10 each
Issued, subscribed and paid up share capital = 400,273,960 Ordinary Shares of Rs. 10.
Earnings per share = Rs. 6.73
Price earning (P/E) ratio = 7.06
Market value per share at year end = Rs. 47.50
Breakup value per share (with revaluation surplus) = Rs. 24.55
Company's Credit Rating

PACRA has assigned long-term and short-term entity ratings of "A-" (Single A Minus) and "A2" (A Two) respectively with Stable Outlook.
[Source: www.gharibwalcement.com]
GCL will support this FYDP project and will provide accommodation and food to the research team members during their visits to GCL site.

8. PROJECT OUTPUT

Please give a brief account of accepted output

Main output of this project will be a new and thermally optimized design of a waste heat recovery system (WHRS) for capturing the waste heat from the rotary kiln surface of a cement plant. This will be a moveable type of WHRS in which hot water will be produced using the waste heat from the kiln’s surface. This high temperature water will then be fed into an absorption cooling system which will generate cooling.

9. FACILITIES AND FUNDING

9A. Facilities: equipment available for the research project IN THE HOST UNIVERSITY/INSTITUTION & THE COLLABORATING OGRANIZATION

- Offices and ANSYS software for thermal modelling is available at the HMT lab of MUST.
- Mechanical workshop of GCL is available for the fabrication of scale down model of kiln and WHRS.

9B. Scientific Personnel (at the Supervisor’s institution)

a. Available 03 B.Sc. Engineering Students

9C. Other funding available for the proposed studies (if any)

N/A

10A. Project Supervisor

A brief resume of research accomplished. Please specify title of the research proposal(s), duration, funding source(s) and award amount(s). Detailed CV can be placed as annex at the end.

With over 22 years of industrial and academic experience, Dr. Khuram holds the title of Chartered Engineer of UK Engineering Council, member of Energy Institute UK, Professional Engineer with PEC and an HEC approved supervisor. Dr. Khuram has vast experience of working in power generation industry and cement industry. Recently he has supervised an MS thesis on the waste heat recovery system for the cement industry’s rotary kiln surface. Results of this thesis show that there is a strong potential for capturing this waste heat from the kiln surface. These results were presented to the higher management of Gharibwal Cement Ltd (GCL). In last few years, Dr. Khuram has attended four international trainings on renewable energy and waste to energy in China and has attended a number of CPD courses to enhance his professional skills. Dr. Khuram has published 31 research papers and has presented five papers in international conferences. Dr. Khuram has won six internal funding projects from ORIC MUST of worth 0.25M each. He has won two research projects from HEC of 12.5 million worth under TDF and NRPU schemes. At current Dr. Khuram teaches Heat and Mass Transfer (HMT) and Heating, Ventilation and

Air Conditioning (HVAC) to undergraduate students, and Thermal Design of Heat Exchangers to MS and PhD students.

10B. Industrial Partner (Profile of Partner industry, Accreditation and Certification, Website, Focal Person Contacts. Email, mobile and landline**)**

A brief Profile highlighting achievement / experience especially concerned with the present proposal.

Mr. Mudassar Farooq has an extensive experience of over 25 years of experience in the cement industry and special skills on the kiln's operation.

10C. CO-Supervisor

A brief resume highlighting achievement / experience especially concerned with the present proposal.

Engr. Nasir Iqbal is currently doing his PhD and has keen interest in the field of heat and mass transfer. He has supervised many FYDPs.

11A. ESTIMATED BUDGET FOR THE PROPOSED RESEARCH PERIOD (Rs. in million, please avoid simple calculations)

Estimated budget for this FYDP is 1 million which will mainly include the fabrication of scale down model of rotary cement kiln, fabrication of WHRS and purchase of measuring equipment.

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Signature Project Supervisor   Date: 12 September 2022

KHURAM PERVEZ AMBER

CHARTERED ENGINEER

5th Nov 1976, Pakistan
UKEC CEng Registration Number: 646475
PEC Registration Number: Mech-31732
Energy Institute UK Registration Number: 36277
Pakistan HVACR Society Registration Number: 051-2-2404

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URL: https://scholar.google.com.pk/citations?user=whNRjHYAAAAJ&hl=en
ORCID ID: **https://orcid.org/0000-0002-2681-3179**

With over 21 years' of professional experience in the fields of energy generation, energy management, sustainability along with academic experience, Khuram is a Chartered Engineer, Member of Energy Institute of United Kingdom, and professional member of Pakistan Engineering Council and Pakistan HVACR Society. Khuram holds a Ph.D. degree and a Master of Science degree in Sustainable Energy Systems from London South Bank University, UK and a Bachelor of Science degree in Mechanical Engineering. Khuram is ex-Energy Manager of the Queen Mary University of London. Khuram's skills center on embedding energy efficiency and environmental objectives into industrial projects and organizations. With numerous international trainings, high impact factor publications, and his vast experience in industrial and community-related projects focusing on energy efficiency, climate change, health, and environment, Khuram is considered as a well-known energy expert in his circles. Khuram has won two major projects which mainly focus on deforestation and health. He has recently received huge appreciation from Mangla Power House authorities for designing and installing a cooling system for 100 MW Francis Turbine which has resulted in financial savings of nearly 20.4millions PKR daily. He has presented his University at different national media channels. Khuram is currently working as Chairperson and Associate Professor in the Department of Mechanical Engineering at Mirpur University of Science and Technology, Pakistan.

PROFESSIONAL AFFILIATIONS

Professional Body	Membership Grade	Membership Number
UK Engineering Council	Chartered Engineer (CEng)	646475
Pakistan Engineering Council	Professional Engineer (PE)	Mech-31732
Energy Institute, United Kingdom	Chartered Energy Engineer & Member	36277
Pakistan HVACR Society	Member	051-2-2404

EMPLOYMENT DETAILS

MIRPUR UNIVERSITY OF SCIENCE AND TECHNOLOGY, PAKISTAN — 21st Oct 2013 to current
Job Title: Chairperson / Associate Professor, Department of Mechanical Engineering

- Overall responsibility for promoting research environment in the Department.
- Overall responsibility for the financial and day to day matters of the department
- Responsible for the motivation and professional development of 31 faculty members.
- Responsible for teaching undergraduate and graduate courses (i.e. Heat and Mass Transfer, Thermodynamic, HVAC, Power Plant, IC Engines, Renewable Energy Technologies, Energy Management, Combined Heat and Power).
- Being a member of the department's board of studies, responsible for curriculum development for new subjects.
- Project director of newly proposed Renewable Energy Research Centre.
- Honored for research projects, especially Hybrid kit for 70cc motorcycles, 110cc hybrid car, mist-less cooling fan and revolving door electricity generator projects.
- Principal Investigator of HEC TDF and HEC NRPU projects of worth 12 Million PKR. Received two Research Excellence Awards
- Co-Principal of recently completed 20kW Solar PV project of worth 11 Million PKR
- Principal Investigator of industrial online Total Dissolved Salts (TDS) monitor project

QUEEN MARY UNIVERSITY OF LONDON, EAST LONDON, UK (Part Time) 1st Jun 2011 to 31st Oct 2012
Job Title: Energy Manager

- Responsible for undertaking detailed energy audits to identify improvement opportunities and to prepare a 2 years carbon reduction project program.
- Responsible for the preparation of the Carbon Reduction Commitment (CRC) evidence pack and for the submission of the CRC annual and footprint reports to Environment Agency.
- Responsible for the annual Display Energy Certificates of a building stock of 104 number of buildings.
- Responsible for undertaking trend analysis for all utilities by analyzing consumption profiles from 2005/6 and onwards
- Responsible for the development of procedures to record and monitor energy data and to prepare templates to record utilities.
- Responsible for undertaking feasibility studies of combined heat and power (CHP) for the University campuses.
- Responsible for developing and implementing strategic briefs for design guides /standards for carbon reduction projects line with industry best practice
- Responsible for attracting external funding agencies.
- Responsible for promoting sustainability across the College

Honors:

- Successfully completed feasibility study of combined heat and power (CHP) for the Charterhouse Square campus; presented a business case to stakeholders to gain approval for funding.
- Successfully planned, managed and completed a SALIX funded lighting control project in the Francis Bancroft building.
- Won the bronze award for the green impact campaign.
- Successfully win a dispute with the University's gas supplier and managed to get a credit amount of £57k

SELF-ENERGY LTD, LONDON, UK (Part Time) 01st Dec 2008 to 31st May 2011
Job Title: Sustainable Energy Engineer

- To develop models for technical, financial and environmental viability of different sustainable technologies
- To prepare project plans and to lead a team of three engineers.
- To undertake site wide energy audits to identify energy savings potentials and to prepare reports putting together a list of carbon reduction project against a simple payback criteria
- To assist organizations in implementing and achieving EN 16001 energy management system
- To undertake feasibility studies for energy efficiency measures and sustainable technologies e.g. CHP, solar and wind etc.
- To assist clients in achieving energy savings by analyzing their buildings weekend energy consumption profiles and suggesting necessary changes in their BMS controls
- To facilitate air conditioning inspections in line with EPBD on clients premises.
- To manage and deliver carbon reduction projects to a range of clients.
- To provide regular briefings and technical support relating to legislative drivers surrounding Carbon and Energy issues to Directors, Operations Managers and Clients

Honors:

- Successfully completed CHP feasibility studies for City University, Brunel University, Winchester University and Kingston University, Kings College, Park Road Leisure Centre, Compton Verney Art Gallery.
- Assisted LSBU in achieving successfully 3.5% energy saving by analyzing weekend energy consumption profiles.

LONDON SOUTH BANK UNIVERSITY, LONDON, UK 1st Jan 2008 to 30th Nov 2008
Job Title: Research Associate (Part Time)

- To develop a technical and financial model to assess and calculate the optimum size of CHP for a large scale CHP district heating scheme funded by London Development Authority for south bank area of London.
- To estimate the heating and cooling loads of the buildings in SBEG area.
- To develop infrastructure network for district heating scheme and to calculate associated infrastructure costs.
- To present report findings to LDA representatives and members of South Bank employers group.

GHARIBWAL CEMENT LTD – 37 MW POWER PLANT 15th Jan 2001 to 25th Sep 2007
Job Title: Maintenance Engineer

- Responsible for schedule and preventive maintenance of plant machinery including 5MWe Wartsila 16V32D engines, ABB Turbochargers, Westfalia F.O. & L.O. purifiers, Heat Exchangers, Compressors, etc.
- To prepare plans for daily, weekly, monthly and annual maintenance activities.
- To motivate and arrange training programs for the professional development of 32 numbers of staff members.
- To prepare maintenance reports highlighting key performance areas for the executives.
- To prepare and manage maintenance budget of £ 3.2 million (equivalent)
- To observe and monitor the performance of all machines before & after maintenance.

ACADEMIC BACKGROUND

Degree / Certificate	University / College / School	Year completed
Engineering Systems and Analysis (Ph.D.)	London South Bank University, London, UK	2009 - 2013
Sustainable Energy Systems (M.Sc.)	London South Bank University, London, UK	2007 - 2008
Mechanical Engineering (B.Sc.)	Islamic University of Technology, Dhaka, Bangladesh	1996 - 2000
H.S.S.C	Post Graduate H/8 College, Islamabad, Pakistan	1993 - 1995
S.S.C	Govt. High School Jutana, Jhelum, Pakistan	1983 - 1993

PROFESSIONAL DEVELOPMENT

- Expert in the operation, maintenance and technical evaluation of Thermal Power Plant's machinery including engines, fuel and lube oil purifiers, heat exchangers, pumps, compressors and boilers.
- Expert in the energy management and in the modeling of energy consumption, generation and forecasting.
- Expert in developing and promoting research environment.
- Expert in teaching core Mechanical Engineering subjects.
- Attended a number of CPD courses in the UK and in Pakistan.
- Attended a number of international trainings
- Supervised at least 20 research projects in the field of Renewable Energy Technologies, HVAC and HMT.
- Currently supervising four Ph.D. scholars and six M-Phil thesis and four B.Sc. Engineering projects.
- Presented research papers in international energy conferences.

Professional Training (Please Start from most recent training and go in descending order)

Training Courses - International				
Course / Title	**Certificate Number**	**Duration**	**Field of Study**	**Institution**
International training workshop on Desert –based wind and solar energy Technology	155509	July, 01, 2019 to July 20, 2019 (20 Days)	Renewable Energy	Inner Mongolia Institute of Scientific and Technological Cooperation and Innovation Development, Hohhot – Ministry of Science and Technology, The Peoples Republic of China
International Training Workshop on Waste to Energy	172111	Oct, 15, 2017 to Oct 30, 2017	Energy generation from waste	Zhejiang University, Hangzhou – Ministry of Science and Technology, The Peoples Republic of China

		(15 Days)		
International Training Workshop on Renewable Energy Power Generation and its Integration into Power Grid	161707	July, 4, 2016 to July 23, 2016 (19 Days)	Renewable Energy	North China Electric Power University, Beijing – Ministry of Science and Technology, The Peoples Republic of China
International training workshop on wind and solar energy application technology based on climatic variation	151820	July, 12, 2015 to July 31, 2015 (19 Days)	Renewable Energy	Inner Mongolia Institute of Scientific and Technological Cooperation and Innovation Development, Hohhot – Ministry of Science and Technology, The Peoples Republic of China
CPD Course on Integrated 15050001 Energy Management Systems with Environmental Management Systems	NIL	16 Oct 2012 (1 Day)	Energy Management	National Quality Assurance (NQA), UK
CPD Course on A862 2010 Part L Building Regulations - London	1354393034	18 Sep 2012 (1 Day)	Energy Management	The Chartered Institution of Building Services Engineers, London, UK
CPD Course on A834 The Carbon reduction commitment	1354392739	10 July 2012 (1 Day)	Energy Management	The Chartered Institution of Building Services Engineers, London, UK
BEMS SALIX funded Investment opportunities	NIL	31 Aug 2011 (1 Day)	Project Management	Energy Services and Technology Association, UK
Training Courses - National				
Course / Title	**Certificate Number**	**Duration**	**Field of Study**	**Institution**
CPD Course on Hybrid Hydro Power by Using Floating Solar PV System in Pakistan	NIL	21 February 2020 (1/2 Day)	Hydro Energy	PEB-Mirpur University of Science and Technology, CPO Program of Pakistan Engineering Council
CPD Course on Smart Metering and its Impact	NIL	06 December 2019 (1/2 Day)	Sustainable Energy Systems	PEB-Mirpur University of Science and Technology, CPO Program of Pakistan Engineering Council
CPD Course on Combined Heat and Power (CHP) Types, Applications and Optimum Sizing	I delivered this short course	22 February 2019 (1/2 Day)	Sustainable Energy Systems	PEB-Mirpur University of Science and Technology, CPO Program of Pakistan Engineering Council
CPD Course on Light Weight Concrete: Prospects and Challenges	NIL	23 February 2018 (1/2 Day)	Sustainable Buildings	PEB-Mirpur University of Science and Technology, CPO Program of Pakistan Engineering Council
CPD Course on Predictive Modelling for Chlorides Ion Penetration Through Cement and Concrete Composites	NIL	29 September 2017	Sustainable Buildings	PEB-Mirpur University of Science and Technology, CPO Program of Pakistan Engineering Council

		(1/2 Day)		
CPD Course on Scope of Solar Energy in Pakistan and Major Challenges	I delivered this short course	25 Aug 2017 (1/2 Day)	Solar Energy	PEB-Mirpur University of Science and Technology, CPO Program of Pakistan Engineering Council
CPD Course on Smart Metering and its Impact	44	28 July 2017 (1/2 Day)	Smart Metering	PEB-Mirpur University of Science and Technology, CPO Program of Pakistan Engineering Council
CPD Course on Fundamentals of Project Management	5254	27 July 2017 (1 Day)	Project Management	Pakistan Engineering Council, Pakistan
CPD Course on Course Management in an Accredited Program with PEO, PLOs and CLOs	17	26 May 2017 (1/2 Day)	Course Management	PEB-Mirpur University of Science and Technology, CPO Program of Pakistan Engineering Council
CPD Course on Technical Report Writing Using LATEX	19	28 April 2017 (1/2 Day)	Report Writing	PEB-Mirpur University of Science and Technology, CPO Program of Pakistan Engineering Council
Starting and Managing Online Business	238	18 Jan 2017 (1/2 Day)	Business Management	Small and Medium Enterprises Development Authority (SMEDA), Pakistan
CPD Course on Project procurement and Contract Management	577	25 Nov 2016 (1 Day)	Project Management	Pakistan Engineering Council, Pakistan
ISNET/SUPARCO Workshop on Students Satellites	NIL	Nov, 04 to Nov 05, 2015 (02 Days)	Satellites	Space and Upper Atmosphere Research Commission (SUPARCO), Pakistan
CPD Course on CPD Framework for Professional Development of Engineers	03531	20 March 2014 (1/2 day)	Professional Development	Pakistan Engineering Council, Pakistan

PUBLICATIONS

Journal Publications

1. **Amber, K. P**., & Parkin, J. (2015). Barriers to the uptake of combined heat and power technology in the UK higher education sector. *International Journal of Sustainable Energy*, *34*(6), 406-416.
2. **Amber, K. P**., Aslam, M. W., & Hussain, S. K. (2015). Electricity consumption forecasting models for administration buildings of the UK higher education sector. *Energy and Buildings*, *90*, 127-136.
3. **Amber, K. P**., Aslam, W., & Bashir, M. A. (2016). Development of a typical hourly electricity consumption profile for student residence halls based on central tendency method. *The Nucleus*, *53*(1), 14-25.
4. **Amber, K. P**., & Aslam, M. W. (2018). Energy-related environmental and economic performance analysis of two different types of electrically heated student residence halls. *International Journal of Sustainable Energy*, *37*(3), 278-293.
5. Bashir, M. A., Ali, H. M., **Amber, K. P**., Bashir, M. W., Ali, H., Imran, S., & Kamran, M. S. (2018). Performance investigation of photovoltaic modules by back surface water cooling. *Thermal Science*, *22*(6 Part A), 2401-2411.

6. Chaudhary, G. Q., Ali, M., Ashiq, M., Ali, H. M., & **Amber, K. P**. (2019). Experimental and model based performance investigation of a solid desiccant wheel dehumidifier in subtropical climate. *Thermal Science*, *23*(2 Part B), 975-988.
7. **Amber, K. P**., Aslam, M. W., Mahmood, A., Kousar, A., Younis, M. Y., Akbar, B., & Hussain, S. K. (2017). Energy consumption forecasting for university sector buildings. *Energies*, *10*(10), 1579.
8. Chaudhary, G. Q., Kousar, R., Ali, M., Amar, M., **Amber, K. P**., Lodhi, S. K., & Ditta, A. (2018). Small-Sized Parabolic Trough Collector System for Solar Dehumidification Application: Design, Development, and Potential Assessment. *International Journal of Photoenergy*, *2018*.
9. **Amber, K. P**., Aslam, M. W., Ikram, F., Kousar, A., Ali, H. M., Akram, N., ... & Mushtaq, H. (2018). Heating and cooling degree-days maps of Pakistan. *Energies*, *11*(1), 94.
10. **Amber, K. P**., Dunn, A., Parkin, J., & Day, A. R. (2018). Development of a combined heat and power sizing model for higher education buildings in the United Kingdom. *Energy and Buildings*, *172*, 537-553.
11. **Amber, K. P**., Hussain, I., Kousar, A., Bashir, M. A., Aslam, M. W., & Akbar, B. (2019). A self-cleaning device for pole mounted solar photovoltaic installations. *Thermal Science*, *23*(2 Part A), 739-749.
12. **Amber, K. P**., Day, T., Ratyal, N. I., Kiani, A. K., & Ahmad, R. (2018). Techno, economic and environmental assessment of a combined heat and power (CHP) system—A case study for a university campus. *Energies*, *11*(5), 1133.
13. **Amber, K. P**., Ahmad, R., Aslam, M. W., Kousar, A., Usman, M., & Khan, M. S. (2018). Intelligent techniques for forecasting electricity consumption of buildings. *Energy*, *157*, 886-893.
14. **Amber, K. P**., Day, A. R., Ratyal, N. I., Ahmad, R., & Amar, M. (2018). The Significance of a Building's Energy Consumption Profiles for the Optimum Sizing of a Combined Heat and Power (CHP) System—A Case Study for a Student Residence Hall. *Sustainability*, *10*(6), 2069.
15. Khan, M. S., Abid, M., Ali, H. M., **Amber, K. P**., Bashir, M. A., & Javed, S. (2019). Comparative performance assessment of solar dish assisted s-CO2 Brayton cycle using nanofluids. *Applied Thermal Engineering*, *148*, 295-306.
16. **Amber, K. P**., Umar, M., Waqas, M., Hussain, I., & Sajid, M. (2018). Effect of different factors on the electricity consumption and electricity usage intensity (EUI) of residential buildings in Pakistan. *Revista de la Construcción*, (3), 473-483.
17. Khan, M. S., **Amber, K. P**., Ali, H. M., Abid, M., Ratlamwala, T. A., & Javed, S. (2019). Performance analysis of solar assisted multigenerational system using therminol VP1 based nanofluids: A comparative study. *Thermal Science*, (00), 62-62.
18. **Amber, K. P**., Ahmad, R., Chaudhery, G. Q., Khan, M. S., Akbar, B., & Bashir, M. A. (2020). Energy and environmental performance of a higher education sector–a case study in the United Kingdom. *International Journal of Sustainable Energy*, *39*(5), 497-514.
19. **Amber, K. P**., Aslam, M. W., Kousar, A., Khan, M. S., Chaudhary, G. Q., & Amar, M. (2020). Energy Usage Intensity of Bank Building Stock: A Case Study in Pakistan. *ASME Journal of Engineering for Sustainable Buildings and Cities*, *1*(2).
20. Abid, M., Khan, M. S., Ratlamwala, T. A., & **Amber, K. P**. (2020). Thermo-environmental investigation of solar parabolic dish-assisted multi-generation plant using different working fluids. *International Journal of Energy Research*.
21. Khan, M. S., Yan, M., Ali, H. M., **Amber, K. P**., Bashir, M. A., Akbar, B., & Javed, S. (2020). Comparative performance assessment of different absorber tube geometries for parabolic trough solar collector using nanofluid. *J Therm Anal Calorim*.
22. Bashir, M. A., Giovannelli, A., **Amber, K. P**., Khan, M. S., Arshad, A., & Daboo, A. M. (2020). High-temperature phase change materials for short-term thermal energy storage in the solar receiver: Selection and analysis. *Journal of Energy Storage*, *30*, 101496.
23. **Amber, K. P**., Akram, W., Bashir, M. A., Khan, M. S., & Kousar, A. (2020). Experimental performance analysis of two different passive cooling techniques for solar photovoltaic installations. J Therm Anal Calorim., https://doi.org/10.1007/s10973-020-09883-6
24. Akbar, B., **Amber, K.P.,** Kousar, A., Aslam, M.W., Bashir, M.A. and Khan, M.S., 2020. Data-driven predictive models for daily electricity consumption of academic buildings [J]. AIMS Energy, 8(5), pp.783-801.
25. Salam, R.A., **Amber, K.P.,** Ratyal, N.I., Alam, M., Akram, N., Gómez Muñoz, C.Q. and García Márquez, F.P., 2020. An Overview on Energy and Development of Energy Integration in Major South Asian Countries: The Building Sector. Energies, 13(21), p.5776.

26. Khan, M.S., Abid, M., Bashir, M.A., **Amber, K.P**., Khanmohammadi, S. and Yan, M., 2021. Thermodynamic and exergoeconomic analysis of a novel solar-assisted multigenerational system utilizing high temperature phase change material and hybrid nanofluid. Energy Conversion and Management, 236, p.113948.
27. Khan, M.S., Abid, M., **Amber, K.P**., Ali, H.M., Yan, M. and Javed, S., 2021. Numerical Performance Investigation of Parabolic Dish Solar-Assisted Cogeneration Plant Using Different Heat Transfer Fluids. International Journal of Photoenergy, 2021.
28. Bashir, M.A., Daabo, A.M., **Amber, K.P.,** Khan, M.S., Arshad, A. and Elahi, H., 2021. Effect of Phase Change Materials on the short-term thermal storage in the solar receiver of dish-micro gas turbine systems: A numerical analysis. Applied Thermal Engineering, p.117179.
29. **Amber, K.P.,** Ahmad, R., Farmanbar, M., Bashir, M.A., Mehmood, S., Khan, M.S. and Saeed, M.U., 2021. Unlocking Household Electricity Consumption in Pakistan. Buildings, 11(11), p.566.
30. Riaz, M.T., Cheema, T.A., Tayyab, M., Khan, A.U.A., **Amber, K.P**., Sajid, M.B. and Park, C.W., 2022. Investigation of free and forced vortex induced thermal energy exchange potential. Sustainable Energy Technologies and Assessments, 52, p.102107.

Conference Publications

1. M.A. Bashir, **Amber, K. P**., Aslam, M.W., Kousar, A., Ahmed, R., Abid, M. (2018). Performance Analysis of a Double Pass Solar Air Heater with and Without Thermal Storage Medium. 12th IIR/IIF International Conference on Phase-Change Materials and Slurries for Refrigeration and Air Conditioning (PCM-2018), Université de Sherbrooke, (Québec), Canada
2. **Amber, K. P**., Aslam, M.W., Kousar, A., Khan, M.S., Chaudhary, G.Q., Amar, M. (2018). Benchmarking the Electricity Usage Intensity of Banking Sector Buildings in Pakistan. 16th International Conference on Clean Energy (ICCE-2018), Eastern Mediterranean University, North Cyprus, Turkey
3. **Amber, K. P**., Aslam, M.W., Kousar, A., Younis, M.Y., Hussain, S. K. and Akbar, B. (2017). Using Multiple Regression Technique for Forecasting Energy Consumption of University Sector Buildings. 10th International Conference on Sustainable Energy and Environmental Protection (SEEP-2017), University of Maribor, Slovenia
4. **Amber, K. P**., Ashraf, N. (2014). Energy Outlook in Pakistan. IEEE International Conference on Energy Systems and Policies (ICESP), Air University, Islamabad, Pakistan
5. **Amber, K. P**., Bilal, S.M. (2014). Techno, economic and environmental feasibility of CHP for a four star hotel. IEEE International Conference on Energy Systems and Policies (ICESP), Air University, Islamabad, Pakistan

Newspaper Articles

- "Conversion of Motorcycles From Fuel To Electric", Dunya Blogs, September 18, 2019
- "National Energy Policy: A dilemma", Dawn Newspaper, Pakistan, February 02, 2013
- "Student Switch-off Scheme" , Daily Times Newspaper, Pakistan, May 5, 2014
- "Saving Energy", Dawn Newspaper, December 29, 2014
- "Use of Solar Lights", Daily Times Newspaper, Pakistan, October 27, 2014

Approved/Awarded Research Projects as Principal Investigator (PI)

No.	Project Title	Funding Agency	Amount (PKR)
1	Development of a Multi-Purposed Environment-Friendly and Efficient Smart Wood Stove	HEC Pakistan	9.3584M
2	Design, Development and Community Adoption of Energy Efficient, Environment Friendly & Cost Effective Smokeless Fuel wood Stove for Hilly Areas of AJK-Pakistan	HEC Pakistan	2.53M
3	A real time wireless monitoring system for Total Dissolve Salts (TDS) level of boiler systems in Industries	ORIC, MUST	0.25M

4	Design, development and experimental testing of a solar assisted remote cold storage	ORIC, MUST	0.25M
5	Design and Development of a Hybrid Kit for CD 70 Motor Cycle	ORIC, MUST	0.25M
6	Design, development and experimental testing of a water wheel	ORIC, MUST	0.125M
7	Design, development and experimental testing of a self-cleaning mechanism for pole mounted solar PV installations	ORIC, MUST	0.125M
Total Amount (Million)			**12.88M**

Research Excellence Awards

S.#	Award Title	Awarded by	Award Year
1.	Research Excellence Award for winning HEC TDF Project Number 02-124	ORIC, MUST	2021
2.	Research Excellence Award for winning HEC NRPU Project Number 7056	ORIC, MUST	2021

REFERENCES

Name	**Prof. Tony Day**	**Dr. M. Waqar Aslam**
Designation	Executive Director	Chairman
Organization	International Energy Research Centre Tyndall National Institute	Mirpur University of Science and Technology
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Telephone	+353 (0)21 234 6950	+92 (0) 5827 960037
Mobile	+353 (0)86 024 5646	+92 (0) 3310445634
E-Mail	tony.day@ierc.ie	waqaraslam271@gmail.com

OTHER INFORMATION

Keen interest in the thermal energy applications and buildings energy management, renewable and clean energy technologies, especially solar, wind and Combined Heat and Power (CHP). Reading industry journals and writing articles on energy efficiency, HMT; attending energy workshops, seminars. Have full UK and Pakistan driving license.