Queensland University of Technology
Faculty of Built Environment and Engineering

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22 November 2012

Prof.Dr. Coskun FIRAT
Istanbul Technical University
Energy Institute
Renewable energy Division
TURKEY

Invitation for academic and research interaction

Dear Professor Firat,

With reference to our recent e-mail communications, I would like to invite you to join our research group as a visiting fellow. Our solar thermal research group includes 2 academics and 3 PhD students. During your stay, you will be involved in the research project titled "development of advanced microwave assisted solar drying system". This project is supported by Queensland Government under smart future fellowship programme and expected to be completed in May 2015. Initially you will be involved in the project for one year which can be further extended. We can share knowledge and experiences in this field and work towards establishing collaboration between your and our Universities.

QUT will provide you all necessary work facilities (e.g. computer, desk, stationary, library facility) during you stay here.

With best regards,

Dr. Azahrul Karim
Senior Lecturer
Course Leader: Master of Engineering Management
Mechanical Engineering Discipline; Science and Engineering Faculty
Queensland University of Technology
Brisbane, 2 George Street, QLD 4001 AUSTRALIA
Tel (07) 3138 6879 Fax: (07) 3138 1516
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October 7, 2013

To Who It May Concern

This is to certify that Dr Coskun FIRAT, Assist.Prof, Istanbul Technical University Energy Institute, Istanbul, Turkey is currently working as a visiting fellow in one of my research projects titled "Development of advanced solar drying system". He has been involved in developing mathematical models of the drying process and implementing these models in Matlab. He is also involved in supervising undergraduate projects at Queensland University of Technology. We have jointly wrote a research papers and more papers are under process. I have found Dr Firat to be innovative in his research and he follows the concept of an idea to completion independently.

He has a very good communication skill and excellent capability to engage with others. He is always ready to accept new challenges.

It is very nice to work with Dr Firat and I wish him success in his future endeavors.

Dr Azharul Karim
Senior Lecturer
Course Leader: Master of Engineering Management
Mechanical Engineering Discipline, Science and Engineering Faculty
Queensland University of Technology
2 George Street, QLD 4001 AUSTRALIA
Tel (07) 3138 6879 Fax: (07) 3138 1529
Email: azharul.karim@qut.edu.au

1. Fellowship overview

Type of Fellowship sought *(nominate **one** type only)*

☒ Early Career Smart Futures Fellowship (**$180,000** over three years, excluding GST)

☐ Mid-Career Smart Futures Fellowship (**$360,000** over three years, excluding GST)

Early Career Fellowships – for applicants with less than 5 years post-doctoral experience.

Mid-Career Fellowships – for applicants with 5-10 years post-doctoral experience.

Note: Allowances will be made for applicants who have taken time away from research, e.g. for parenting or illness, provided this is explained in the application.

Provide a brief, plain English Smart Futures Fellowship **title**.

Development of an efficient and cost effective solar drying system

Provide a plain English description of the proposed fellowship research and the likely outcomes for Queensland. *Please refer to **Note 1**. (maximum 100 words)*

Drying of agricultural products consumes 20-25% of the energy used by food processing industry usually by burning diesel or gas. However, a well designed solar dyer can significantly reduce the dependence on fossil fuel. Based on applicant's extensive relevant previous and current work, this project will develop an efficient, reliable and economically attractive solar drying system. A prototype solar dryer will be constructed using most efficient v-groove collector and thermal storage method developed by the applicant. Extensive experiments will be conducted to demonstrate the superior performance of the system and to establish design guidelines and economic viability. Queensland has a plethora of space and resources available to take advantage of the energy of the sun. This invention will benefit farmers, grain, fruit, vegetable and timber drying companies, equipment manufacturers and researchers and policy makers involved in alternative energy sources.

2. Name of applicant

Name *(including title)*	Azharul Karim
Gender	☒ Male ☐ Female

3. Employer

Name of your employer	Queensland University of Technology
Name of institute/school	School of engineering system

4. Applicant's contact details

Work address (for courier)	2 George Street, QLD 4001 AUSTRALIA		
Phone	31386879	Mobile	0422343395
Email	azharul.karim@qut.edu.au		

5. Citizenship details

Of which country/countries do you currently hold citizenship?

Australia

If you are not an Australian citizen, indicate your current Australian residency status.

6. Research qualification *(applicants must have a PhD or equivalent)*

Research qualification	PhD
Research field	Product Quality and Reliability
Institution attended	Melbourne University
Date qualification awarded	2007

7. Eligibility

Do you have **matched cash funding** from your sponsoring organisation/s?	☒ Yes ☐ No
Will your **sponsor** be your employing organisation?	☒ Yes ☐ No
Will you be employed in a full-time capacity and spend at least **50 per cent** of your time on the proposed fellowship?	☒ Yes ☐ No
Will you **reside** in Queensland for the duration of the fellowship?	☒ Yes ☐ No
Will the fellowship research be **new**, and not part of an existing project?	☒ Yes ☐ No

8. Sponsoring organisation (the Sponsor)

The sponsoring organisation will employ the fellow and the Department will make the government's Smart Futures Fellowship payments to the sponsor. Suitable sponsoring agencies are Queensland universities, government agencies, research institutes, and company/industry research facilities.

Name of organisation	Queensland University of Technology		
Registered for GST?	☒ Yes ☐ No	ABN	83 791 724 622
Web address	http://www.qut.edu.au/		
8.1 Contact person *(Fellowships co-ordinator)*			
Name *(including title)*	Michael McArdle		
Position title	Director, office of research		
Address	*If applicable, include the building name and/or number for courier deliveries.* Queensland University of Technology, 2 George Street, QLD 4001 AUSTRALIA		
Phone	07-31385376	Mobile	
Email	m.mcardle@qut.edu.au		

9. Co-sponsors *(if applicable)*

Applicants for Smart Futures Fellowships may have one or more co-sponsoring organisations which contribute cash to the proposed fellowship. Industry co-sponsorship is desired, but not compulsory.

9.1 Co-sponsor one			
Name of organisation			
Address			
Registered for GST?	☐ Yes ☐ No	ABN	
Web address			
Contact person			
Name *(including title)*			
Position title			
Phone		Mobile	
Email			
9.2 Co-sponsor two			
Name of organisation			
Address			
Registered for GST?	☐ Yes ☐ No	ABN	
Web address			

Contact person			
Name *(including title)*			
Position title			
Phone		Mobile	
Email			

10. Cash budget (excluding GST) – *please refer to **Note 2.***

Note: The Queensland Government's Smart Futures Fellowship funding **must** total either $180,000 (early career fellowships) or $360,000 (mid-career fellowships) over three years. The state's funding must be matched by combined sponsor and co-sponsor cash funding of at least 1:1.

10.1 Cash funding ($)

Funding Provider		Year 1 ($)	Year 2 ($)	Year 3 ($)	Total ($)
QGSFF*	salaries	46929	50154	53553	150636
	other costs	20000	0	9364	29364
	Total [a]	66929	50154	62917	180000
Sponsor	salaries	57402	59698	62086	179185
	other costs	30000	5000	5000	40000
	Total [b]	87402	64698	67086	219185
Co-sponsor one *(if applicable)*	salaries				
	other costs				
	Total [c]	0	0	0	0
Co-sponsor two *(if applicable)*	salaries				
	other costs				
	Total [d]	0	0	0	0
Grand Total ($) [a+b+c+d]		154331	114852	130003	399185

* QGSFF = Queensland Government Smart Futures Fellowship funding.

10.2 Budget justification

Provide details of all salary costs and other fellowship costs.

A) SALARIES: Funding is requested for 50% of my and a full time research assistant's salary. The research assistant will be assisting me in designing and constructing of the experimental setup and collecting and analysing experimental data. Total salary of the RA is estimated as $150636 over three years and is requested from QGSFF. I will spent 50% of my time in this project and QUT will pay my salary, which is estimated as $179185 over 3 years.

B) OTHER COSTS (Total $69,364): B1.1 Experimental Setup: a prototype drying system will be designed and constructed to experimentally investigate the designed dryer and to demonstrate as a model dryer. The cost of the prototype is estimated as $50,000, of which QUT will pay $30,000 and $20,000 is requested from QGSFF.

B2.2: Maintenance of the prototype dryer: Funding is requested for the cost of maintaining the prototype dryer which estimated to be $5,000 per year and QUT will contribute this.

B2.3: TRAVEL COSTS: Attendance at reputed conferences is essential to demonstrate the findings of this research and to disseminate the gained knowledge. Total travel budget related to this project is estimated as $9,364.

11. Fellowship staff and location

List the members of your proposed fellowship research team. Identify the team leader.

(maximum 300 words)

The core of the research team will be the SOLAR THERMAL RESEARCH group (Dr Azharul Karim, A/P Richard Brown, Dr Wiji Senadera and Dr Sabrina Fawzia), led by Dr Karim at QUT, The Research Assistant to be employed, Dr Mohammad Rasul of CQUniversity, and Professor Hawlader of National University of Singapore.

Dr. Azharul Karim (Team Leader): will be responsible for managing the project. He is the foremost expert in solar thermal energy and drying technology research, having developed most efficient solar air collector, dryer for tropical fruits, efficient cold thermal storage and complex drying model of tropical fruits. Dr Karim is world known for his innovative product developments as demonstrated by his innovative new products and international patents. He has successfully completed many research projects. Therefore, he will be responsible developing mathematical models for the components of the dryer, designing and developing the prototype test systems and coordinating the whole direction of the project. Professor Hawlader is world known for solar energy research with 30 years of experience. He has extensive experience in solar drying, heat pump drying, solar collector and energy efficiency. Dr Karim and Prof Hawlader pose complementary expertise and have been successfully working in collaboration for last 6 years. Prof Hawlader has kindly agreed to contribute to the project.

Solar thermal research group at QUT is active in the research areas of solar thermal storage, solar drying, solar air conditioning, solar desalination, and solar collector development. Dr Fawzia is expert in finite element modelling and will be responsible for numerical analysis of the systems. A/Prof Brown and Dr Senadera will help in experiments and analysis. Dr Mohammad Rasul is experienced with design and development of renewable energy systems and will contribute to the development of the proposed system.

Research Assistant (RA): will have knowledge of programming, experimental data collection and analysis. The RA will be primarily responsible, though not limited to, for developing computer codes to solve mathematical models developed by Dr Karim, running the experiments, data collection and analysis. The RA will also assist in verifying of the models by experimental data.

Provide the number of Queensland-based **jobs** you expect will be funded by the fellowship, including the Fellow. Please provide full-time equivalent details (e.g. 2.5 FTE).

Existing jobs	0.5 FTE	New jobs	1 FTE	Total Jobs	1.5 FTE

Where will you be based if you secure the fellowship (agency name and city/town)?

Brisbane

Do you have an **industry** sponsor or co-sponsor? ☐ Yes ■ No

If **yes**, briefly outline the industry interest and involvement in the fellowship.

(maximum 100 words)

12. Assessment criteria

The merit of your application will be evaluated by an independent assessment panel according to how you address the assessment criteria. Please keep your application as concise as possible and within the recommended maximum ***word limits.***

12.1 The person: *applicants with proven research and leadership skills (30 per cent weighting).*

Provide a brief overview of your relevant research experience and leadership skills. *(maximum 500 words)*

I have made significant contributions in the areas of Solar energy and innovative product development and my research and scholarship activities demonstrate a high level of competence. Development of many innovative products and publication of 65 high quality, high impact peer-reviewed papers with more than 170 CITATIONS and h-index of 8 and two INTERNATIONAL PATENTS established my international standing . Few of my innovative development include:

(a) I have developed the highly efficient stratified chilled water thermal storage air conditioning system using an OCAGONAL DIFFUSER. The technology developed is currently used by Telecom Malaysia in its thermal storage A/C systems.

(b) I am the inventor of energy and water efficient Ultrasonic washing machine (patent WO02089652; and Ultrasonic dishwasher (patent no. WO0229148; Main features: 1. Cleans dishes in just 2 minutes; 2. Cleans irregular shaped items, which conventional dishwashers are unable to wash, 3. Saves 65% energy, 4. Cold wash).

(c) During my Master of Engineering at National University of Singapore, I have developed the world's MOST EFFICIENT AIR COLLECTOR[1-2] (efficiency as high as 82%) for drying purpose and complex MATHEMATICAL MODELS [3-4] to study drying dynamics. Drying models help to understand drying kinetics, which eventually helps to design optimum drying parameters (air temperature, air velocity, drying time, air humidity, length and width of the dryer, dimensions and number of trays etc).

(d) I am one of the pioneer researchers in Australia in LEAN MANUFACTURING area as demonstrated by my high quality PhD thesis and many publications in highly ranked journals.

Therefore, proposed research work will be based on my internationally recognised skills and expertise in this area. Currently two PhD and two masters students are working in solar thermal research under my supervsion. Researchers often overlook manufacturability, quality and cost of a product during their inventions and therefore fail to commercialize. With my expertise in LEAN manufacturing, I will take these account in the proposed invention to develop the high quality, easily manufacturable and commercially competitive product.

Throughout my research career, I lead different research and product development projects involving $1.7million GRANT. My commendable expertise in solar energy, solar drying and new product development and research project management capability at both academic and industry environment confirms my ability to plan and complete new projects with available resources within tight time frame.

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1. M. A. Karim and M.N.A. Hawlader, Development of solar air collectors for drying applications, Energy Conversion and Management, 45 (2004) 329–344. citations- 36 (ISI Impact factor: 1.944, ERA ranking –B)
2. M. A. Karim and M.N.A Hawlader, Performance evaluation of a v-groove solar air collector for drying applications, Applied Thermal Engineering, 28 (2006) 121–130, citations- 19, (ISI Impact factor: 1.922, ERA ranking –A)
3. M. A. Karim and M.N.A. Hawlader, Drying characteristics of banana: theoretical modelling and experimental validation, Journal of Food Engineering, 70 (2005) 35–45. citations- 40 (ISI Impact factor: 2.313, ERA ranking –A)
4. M. A. Karim and M.N.A Hawlader, Mathematical modelling and experimental investigation of tropical fruits drying, International Journal of Heat and Mass Transfer 48 (2005), 4914-4925. citations- 30 (ISI factor: 1.922, ERA rank A)

List your ***tertiary qualifications****, commencing with your most recent award, in the table below.*

Year conferred	Award received	University	Research fields or course majors
2007	PhD	Melbourne University	Product quality and reliability
1999	Master of Engineering	National Univ. of Singapore	Solar drying
1992	Bachelor of Engg (Hons)	Chittagong University of Engg	Mechanical Engineering

*List the **research positions** you have held over the past **six years**, commencing with your current position, in the table below.*

Dates employed	**Position held**	**Employer** *(group & agency)*	**Role** *(brief description)*
Feb, 2008	Lecturer	QUT	Teaching & Research
Nov 2006	Research Fellow	RMIT University	Research
July 2002	PhD Research Scholar	Melbourne University	Research

*List the **current** research grants you hold as **Project Leader** or **Chief Investigator** in the table below.*

Funding provider	**Funding secured ($)**	**End date**	**Project title**
QUT ECR Grant	10,000	Dec 2011	Solar thermal storage
QUT Ecard Grant	10,000	Dec 2011	Integrated Lean information Model

List the research awards, medals and prizes you have received.

• Prestigious Commonwealth Government IPRS Scholarship during PhD study at Melbourne University
• National University of Singapore top category Research Scholarship during M.Eng study
• Two international patents, 2 book Chapters, 65 publications in peer reviewed high ranked international Journals and conference proceedings, 170+ citations.
• Chancellor award for excellent undergraduate results
• Far Eastern Economic Review Young Scientist award nomination
• Nine research grants with total amount $1.7 million

List the patents you have lodged (filed and pending).

1. Patent number: WO02089652. Ultrasonic Washing machine (Main Features: 1. Capable of gentler and cleaner clothes cleaning. 2. Saves 35%, energy and 25% water 3. Cold wash),
2. Patent number: WO0229148- Ultrasonic dishwashing system (Main features: 1. Cleans dishes in just 2 minutes; 2. Cleans irregular shaped items, which conventional dishwashers are unable to wash, 3. Saves 65% energy, 4. Cold wash).
3. Provisional patents: A. Ultrasonic commercial dishwasher B. Ultrasonic glass cleaner C. High frequency, low cost ultrasonic transducer

12.2 Research outcomes: ***projects which will deliver short-to-medium term (5 to 10 years) outcomes for Queensland and make tangible contributions to the Toward Q2 targets (30 per cent weighting).***

Discuss the expected short to medium term **outcomes** of the fellowship for Queensland and the Towards Q2 targets. Please indicate when you expect the outcomes to be delivered. *(maximum 500 words)*

Proposed innovation will significantly contribute to Queensland's economic, environmental and regional development.

ECONOMIC: Rural QLD comprises 23% of the state economy, with only 3.2% of the nation's population. Rural QLD has a major share in $126 billion local food sales and $24 billion food export. However, lack of proper processing causes considerable damage and wastage of agricultural products [5]. On the other hand, although Australia exports $24 billion worth of food, at the same time $10 billion worth of food, 93% of which is processed food [5]. Most of the imported foods are also grown in Australia and we import these foods because of lack of cost effective and efficient drying industry. A well designed, efficient, low cost, independent and reliable solar drying has the potential to provide very low cost heat and therefore drastically reduce postharvest losses and trigger possibility of establishing many drying/food processing industries in rural QLD. Despite the small share of processed food industry, it is still Australia's largest manufacturing industry, accounting for 21.3 % of total manufacturing turnover and 18 % of employment [5]. This invention has the potential to significantly expand this sector and will employ more people contributing to Q2 target of creating a diverse economy powered by bright ideas (STRONG).

ENVIRONMENTAL: Wholesale energy price increase of 35-40% is projected within 5 years of the introduction of a Carbon Pollution Reduction Scheme (CPRS) [6]. QLD economy is projected to suffer greater reduction in Gross State Product following the introduction of the CPRS, under any scenario [6]. Therefore it is critical for the QLD Government to address the key issue of preparing the QLD Energy and industry sector for these changes – and make the Economy "solar ready". Food drying consumes about 20-25% of the total energy in the food processing industry. Current research will offer an efficient solar drying process to reduce the dependence of traditional energy and thus will help to address the issue of carbon footprint Target 2020 (GREEN). Traditionally dryers are designed without knowing the drying kinetics. This research will develop INNOVATIVE METHODOLOGY to design the dryers based on drying kinetics and will determine the exact energy necessity of drying and therefore significantly reduce energy consumption.

[5] DAFF, Australian agriculture and food sector stocktake, Department of Agriculture, Fisheries and Forestry. Accessed 11/3/2011 from http://www.daff.gov.au/

[6] Australia's Low Pollution Future – the Economics of Climate Change Mitigation, Chapter 6,

Who are the target **end users** of the proposed research and what are the likely benefits of the research to the end users? Please indicate when the research findings/outcomes are likely to be utilised by the end users. *(maximum 500 words)*

The target end users are farmers, grain dryers, fruit and vegetable drying companies, equipment manufacturers and researchers and policy makers involved in alternative energy sources, particularly the use of solar thermal energy

Farmers: Gas fired crop drying is widely used in Australia, which is both expensive and harmful to environment. Lack of proper processing causes considerable damage and wastage of agricultural products, which is estimated to be 30–40% in developing countries [7]. A well designed solar dryer has the potential to drastically reduce this waste. Moreover, considerable amount of fruits and vegetables are unsold and unused every year. Farmers just throw them away towards the end of the season. With the help of proposed solar dryer, farmers will be able to preserve these fruits and vegetables low cost and environmentally friendly manner and will be able to sell in local and international market.

Food industries: The processed food and beverage industry is Australia's largest manufacturing industry, accounting for 21.3 % of total manufacturing turnover and is one of only two manufacturing sectors that are net exporters. Drying consumes 20-25% of the total energy in the food processing industry usually by burning diesel or gas. Huge amount of excess energy is used as dryers are designed without knowing the drying kinetics. Proposed innovative solar dryer will reduce the cost of drying significantly and will make their product more competitive in the international market.

Equipment manufacturers: Efficient, cost effective and reliable solar dryers will have a huge market in Australia, rapidly growing Asian countries and New Zealand. Queensland based manufacturers will be able to manufacture these dryers is mass scale and sell in these countries.

Research Community and policy makers: This will be an innovative new development and answer many questions research community in this area has long been enquiring.

[7]. M. A. Karim and M.N.A. Hawlader, Development of solar air collectors for drying applications, Energy Conversion and Management, 45 (2004) 329–344.

List any **new** national and/or international research collaborations likely as part of the proposed fellowship, and the benefits to be leverage from the collaborations. *(maximum 500 words)*

REGIONAL: At QUT, a group of successful researchers and academics has formed SOLAR THERMAL RESEARCH group. Main members of the group are Dr Azharul Karim, A/P Richard Brown, Dr Wiji Senadera and Dr Sabrina Fawzia and 11 PhD students. This research group has collaboration with other schools at QUT and regional Universities CQUniversity, USQ and James Cook University. As the solar thermal research group will actively involve on this project, further in-house and regional collaborations will be strengthened.

NATIONAL: I am an active member of Solar Integration Australia where James Cook University (Townsville) and CQUniversity (Rockhampton) are part. At national level Solar Integration Australia include Murdoch University, Wollongong University and Dyesol Ltd. Nationally I have research collaboration with RMIT university, Melbourne University and UniSA. This research will indirectly involve these universities and therefore a national collaboration will be strengthened.

INTERNATIONAL: At International level, I have collaboration in Solar research with national University Singapore and Tokyo Institute of Technology, Japan. Professor Hawlader of National University Singapore is a world renowned academic in renewable energy. He was my supervisor during my M.Eng at NUS and he has agreed to actively involve himself in the project. We have demonstrated our collaboration by writing joint conference and journal papers and visiting each other's institutions. Professor Hawlader lectured a seminar at QUT in 2009 and I was invited by National University of Singapore (NUS) in 2010. I spent about 6 weeks in and pursued joint research with NUS. In November 2010 I have also visited University Technology Malaysia and discussed about prospects of solar drying. The have shown keen interest in solar drying as it has a strong market potential in Malaysia. Therefore, I am convinced that significant international collaboration will take place based on the fellowship project.

Discuss the relevance of the proposed research to the activities of **Queensland Government departments and agencies,** and list any proposed collaborations with these groups (if applicable). *(maximum 300 words)*

Proposed research is very relevant to Queensland government priority areas, particularly Department of Environment and Resource Management. The outcome of the research will significantly help to achieve Q2 targets.

12.3 Research proposal: *research which is well planned, technically sound and achievable (40 per cent weighting).*

List the objectives of the proposed fellowship research. *(maximum 300 words)*

The overall goal of the fellowship is to develop highly efficient, cost effective, independent (of traditional power supply) and reliable solar drying system by using comprehensive theoretical and experimental study. Specific objectives are:

1. Develop mathematical models to study complex drying mechanism of fruits and vegetables. Energy required to dry a certain amount of fruits depends on its drying kinetics/mechanism and diffusion coefficient. For example, energy required for extracting one kg of water from apple is not same as extracting the same from banana. Also energy required for extracting certain amount of water at the beginning of drying is different from doing the same towards the end of drying process. Modelling drying mechanism will help to determine the exact energy requirements for drying at different stages of drying and also determine right drying conditions for high quality product.
2. Develop theoretical models for pebble bed thermal storage system for storing excess solar heat for later use and develop optimization models for complete drying system, which will help determine optimum operating conditions for drying.
3. Based of theoretical results, design and construct a prototype solar drying system with v-groove collector and pebble bed storage.
4. Conduct wide range of tests to a) understand drying characteristics of fruits and vegetables at different operating conditions b) validate the mathematical models developed for drying mechanism and for the dryer, c) determine optimum drying conditions, d) determine the energy usage for drying, e) Determine the reliability of the system developed and f) economic analysis if the system
5. Develop design guidelines for solar dryer with details of material selection, manufacturability, reliability, maintenance requirement and cost.

Provide details of the research you will undertake. *(maximum 1000 words)*

Understanding the drying kinetics/ mechanism is important for achieving energy efficiency in drying. For example, energy required for extracting one kg of water from apple is not same as extracting the same from banana. Also energy required for extracting certain amount of water at the beginning of drying is different from doing the same towards the end of drying process. Material moisture content is reduced with drying time and therefore may not require as much as heat it needs at the beginning. Therefore, use of hot air for drying without knowing drying mechanism and behaviour results in wastage of heat and deterioration of food quality. Accurate modelling of drying process will help to determine the exact energy requirements at different stages of drying and also determine right drying conditions for high quality product. This project will develop complex, mathematical model to study the drying mechanism and based on that results, an efficient and reliable dryer will be developed.
Traditionally solar dryers use solar water collectors. As hot air is needed for drying, an extra heat exchanger is required to produce hot air which increases cost and reduces efficiency. These dryers cannot work independently as these do not have storage. For drying applications, air collectors are most suitable as the warm air can be used directly, eliminating any need for an extra heat exchanger. The design of suitable air collectors is one of the most important factors controlling the economics of solar drying [1]. In this study, most efficient air collector and pebble bed storage system developed by me will be used. Detail design and manufacturing guidelines and optimum operating conditions for different environmental conditions will be developed.

APPROACH AND METHODOLOGY: The project has been subdivided into a number of targets as described below:

STAGE 1(0-12 Months): Mathematical modelling and Simulation- In this study, based on my highly scholarly work [4], a mathematical model will be developed to understand the heat and mass transfer phenomena that take place during drying (material model). Heat and mass transfer model for the dryer, termed as equipment model, will also be developed to determine the changes of drying potential of the drying medium during drying. This model describes the transfer process in the dryer and predicts the instantaneous drying capability of air at any time and any location of the dryer. Thus, the model is capable of predicting the dynamic behaviour of the dryer. A reliable dryer model, which can express accurately the drying kinetics of the product as well as predict the drying behaviour of the air and the materials to be dried will be a significant innovation. This type of model can be used as a design tool for the dryer.
Based on preliminary work [8], theoretical model for pebble bed thermal storage system will be developed to investigate performance of such storage in storing solar energy. Optimization models for complete drying system, which will help determine optimum operating conditions for drying will then be developed. A computer code in C# will be developed to solve these mathematical models.

STAGE 2 (6-18 months): Design and build solar drying test facility: This involves detail design and construction of the test facility/prototype dryer based on the results of theoretical study in stage 1. A prototype system will comprise of A. V-groove double-pass air collector to produce hot air from solar radiation [2] B. a cabinet type drying chamber which holds the product to be dried C. a dehumidification module to reduce the moisture content of the air from the drying chamber for reusing it and thus reducing the energy requirement D. Pebble bed thermal storage to store excess energy for use when there will be not solar radiation (i.e. at night)
In addition to the main modules, the system will include air fans and measurement instruments such as thermocouple, load cell, humidity transmitter etc. Detail design of individual components as well as the entire system will be done with careful consideration of materials, space constraint, cost, manufacturability and ergonomics. Design and construction of the test facility can be done in parallel to the mathematical modelling.

STAGE 3 (18-30 MONTHS): Experimental study: Experiments will be conducted to 1) determine thermal performance of v-groove solar air collector 2) determine the drying coefficient and drying characteristics/kinetics, which will eventually determine energy requirement for drying 3) performance of pebble bed thermal storage 4) determine overall performance of the drying system 5) determine the reliability of the prototype and 6) influence of operating variables on the performance of the system. Test results will be compared with the simulation results to validate the models.

STAGE 4 (24-36 Months): economic analysis, Design and construction guidelines, promotion and reporting: Based on data collected during the experiments, an economic and cost analysis will be conducted to determine the cost of the system and operation at commercial scale and to demonstrate economic viability of the invention in comparison of traditional dryers. Based on the findings of the study and my extensive background in manufacturing, design and manufacturing guidelines of solar drying system will be developed.
8. M. A. Karim, Development of solar drying system for tropical fruits, M.Eng thesis, National University Singapore

Describe how the proposed research is **different** from other research in this field.

(maximum 300 words)

Realising the importance and benefits of solar drying, Australian Government funded solar drying projects in the past including a recent project [9]. However, these projects did not achieve expected outcomes due to some fundamental drawbacks. Major drawbacks include (1) dryers were designed without knowing the drying kinetics of food to be dried (2) dryers used (expensive) solar water collectors and therefore required extra heat exchanger (increasing the cost and reducing efficiency) to produce hot air (3) auxiliary heat supply from traditional sources was necessary due to the lack of solar thermal storage (4) manufacturability, reliability and cost effectiveness of construction was not considered. Because of these drawbacks, the solar dryers did not achieve expected efficiency, required large capital cost, were not cost effective and had long payback period.

Proposed project will overcome these drawbacks and will develop a highly efficient, cost effective, reliable and independent solar dryer for agricultural products. Understanding the drying mechanism is important for achieving energy efficiency and this project will develop mathematical models to study the complex drying mechanism. I have conducted extensive research on low cost solar air collector development [1-2]. Proposed dryer will use highly efficient (82%) v-grove collector and thermal storage system developed by me. As solar dryers are exposed to the open environment, reliability of the dryers is a big concern. Extensive reliability study will be conducted to develop a reliable solar dryer. The dryer will be simple in design and will use locally available low cost materials and thus will be very cost effective. Intelligent use of energy (based on drying model), highly efficient collector and thermal storage will further make the dryer very cost effective and result in very low operating cost.

9. Developing a Solar Drying Machine for Agricultural Products, Kame Khouzam, Rural Industries Research and Development Corporation 09/026, 2009 (https://rirdc.infoservices.com.au/items/09-026)

12.4 Research Milestones - List the research milestones and corresponding performance indicators for each year of the proposed fellowship in the table below (maximum of five per year). Please use plain English when writing your milestones. **See Note 3.**

Year 1 Milestones	Year 1 Performance Indicators	Completion Date
1.1 a. Establish Research Team b. Mathematical model for drying of shrinkage material (Fruits, vege, timber)	1.1 a. Appointment of RA b. Generate drying characteristic curves from the mathematical model	6 months after Commencement Date.
1.2 Mathematical model for air collectors	1.2 Efficiency calculation at diff climatic cond.	12 months after Commencement Date.
1.3 Optimization model for entire dryer	1.3 Develop optimum drying conditions	
1.4 Design prototype dryer	1.4 Prepare BOM for components and instru.	
1.5 Construct the prototype dryer	1.5 Prototype ready to conduct initial trials	
Year 2 Milestones	**Year 2 Performance Indicators**	**Completion Date**
2.1 Experiment with solar collector	2.1 Determine thermal performance	24 months after Commencement Date.
2.2 Drying test	2.2 Determine the drying characteristics to	
2.3	2.3 determine energy requirement for drying	
2.4 Test overall performance of drying syste	2.4 Determine optimum operating condtions	
2.5 Reliability test	2.5 Establish life of the dryer at diff env. cond.	
Year 3 Milestones	**Year 3 Performance Indicators**	**Completion Date**
3.1 Validate the models	3.1 Models are validated by exp results	36 months after Commencement Date.
3.2 Economic analysis	3.2 Establish economy and payback period	
3.3 Design guidelines	3.3 Complete detailed design guidelines	
3.4 Prototype demonstration	3.4 Prototype ready for demonstration	
3.5 Patent application	3.5 Submit patent application	

13. Publications

List your peer-reviewed publications for the last **five years**.

Since 2006 I have a total of 35 (consisting of 16 journal papers, 1 book, 1 book chapter, and 15 refereed conference papers) high quality, high impact peer-reviewed papers with more than 170 CITATIONS and h-index of 8 A detailed list is provided in the attachment; following are selected publications:

Journal Papers

1. M. A. Karim and M.N.A Hawlader, Performance investigation of flat plate, v-corrugated and finned air collectors, Energy, Volume 31, Issue 4, March 2006, Pages 452-470. (ISI impact factor- 0.935), citations-Google 17, Scopus 15 (ISI Impact factor: 2.952, ERA ranking –C)
2. M. A. Karim and M.N.A Hawlader, Performance evaluation of a v-groove solar air collector for drying applications, Applied Thermal Engineering, 28 (2006) 121–130. (ISI impact factor- 0.814), citations-Google 19, Scopus 16 (ISI Impact factor: 1.922, ERA ranking –A)
3. M. A. Karim. (2011) Experimental investigation of a stratified chilled water thermal storage system, Applied thermal engineering, Vol 31, pp1853-1860. (ISI Impact factor: 1.922, ERA ranking –A)
4. M. A. Karim, A. J. Smith and S. Halgamuge, Manufacturing Yield improvement by Clustering, Lecture notes in

14. Professional activities

List your other professional appointments and roles that are relevant to the fellowship application, for example adjunct positions and committee memberships.

Current/Recent appointments:

1. Course Leader-Master of Engineering, QUT
2. Member of Faculty infohub committee, QUT
3. Served as member of student liaison committee
4. Supervising 8 Masters/PhD students
5. Coordinator of 6 units undergraduate and postgraduate units
6. Lead a group of ECARD academics at QUT
7. Member of Engineers Australia and American Society of Quality
8. Regular reviewer of 8 reputed Journals

Past appointments:

1. Worked as Head of R & D at JCS Automation Singapore from 1999 to 2002. My responsibility was to develop innovative new products. I received S$1.1 million grant from Singapore Government to develop ultrasonic washing machine.
2. Worked as Research assistant at University of Technology Malaysia where I developed chilled water storage system

15. Referees

Provide the names and contact details of two referees who are able to comment on your suitability to undertake the proposed fellowship. Referee comments may be taken into account as part of the assessment process.

15.1 Referee one

Name *(including title)*	Professor Prasad Yarlagadda		
Name of organisation	QUT		
Position title	Professor and Head of Research, Mechanical and Manufacturing Discipline		
Work postal address	QUT, 2 George Street, Brisbane, 4001		
Phone	31385267	Mobile	0434072608
Email	y.prasad@qut.edu.au		

15.2 Referee two

Name *(including title)*	Professor Saman HALGAMUGE		
Name of organisation	Melbourne University		
Position title	Professor and Deputy Dean		
Work postal address	The University of Melbourne, Vic 3010, Australia		
Phone	03-83445587	Mobile	
Email	saman@unimelb.edu.au		

16. Other Smart Futures Fund applications

Have you applied for other funding under the current round of the Smart Futures Fund?

☐ Yes ■ No

If **yes**, provide the name/s of the program/s and the associated project title/s.

Is this application for a Smart Futures Fellowship contingent upon securing other Smart Futures Fund funding, that is, you can not undertake the Smart Futures Fellowship without the other funding? ☐ Yes ■ No

If **yes**, why is the Smart Futures Fellowship contingent on securing the other Smart Futures funding?

17. Due diligence and probity assessments

Provide details of the key individuals in sponsoring and co-sponsoring organisations (for example, chief executive officers or key researchers). This information may be used to carry out due diligence and probity assessments.

*Do **not** provide details for sponsors or co-sponsors that are Queensland Government agencies.*

17.1 Sponsor

Name of organisation	QUT

Key individual one

First name	John	Middle name/s	Marcus	Last name	Bell
Date of birth	5/12/1957	City and country of birth		Hornsby, Australia	

Is the individual named above a relative* of a current Member of Queensland Parliament?

☐ Yes ■ No If **yes**, provide the member's full name.

Key individual two

First name	Arun	Middle name/s	Kumar	Last name	Sharma
Date of birth	25/07/1962	City and country of birth		Banmankhi, India	

Is the individual named above a relative* of a current Member of Queensland Parliament?

☐ Yes ■ No If **yes**, provide the member's full name.

17.2 Co-sponsor one					
Name of organisation					
Key individual one					
First name		Middle name/s		Last name	
Date of birth		City and country of birth			
Is the individual named above a relative* of a current Member of Queensland Parliament? ☐ Yes ☐ No If **yes**, provide the member's full name.					
Key individual two					
First name		Middle name/s		Last name	
Date of birth		City and country of birth			
Is the individual named above a relative* of a current Member of Queensland Parliament? ☐ Yes ☐ No If **yes**, provide the member's full name.					
17.3 Co-sponsor two					
Name of organisation					
Key individual one					
First name		Middle name/s		Last name	
Date of birth		City and country of birth			
Is the individual named above a relative* of a current Member of Queensland Parliament? ☐ Yes ☐ No If **yes**, provide the member's full name.					
Key individual two					
First name		Middle name/s		Last name	
Date of birth		City and country of birth			
Is the individual named above a relative* of a current Member of Queensland Parliament? ☐ Yes ☐ No If **yes**, provide the member's full name.					
***** *For the purpose of completing this section of the application, a relative of a Member of Parliament is defined as any of the following: spouse, mother, mother in-law, father, father in-law, sister, sister in-law, brother, brother in-law, daughter, daughter in-law, son or son in-law.* *If the space provided above is not sufficient, additional information can be provided as an attachment.*					

18. Financial Incentive Agreement declaration

With reference to my application for a Smart Futures Fellowship,

I, Dr Azharul Karim *[insert applicant's name]*, (the applicant):

1. authorise the Department of Employment, Economic Development and Innovation ("the Department") to undertake any necessary checks subject to any written notification as to confidentiality provided to the Department;
2. declare that:
   (a) the information supplied in my application and research plan is true, accurate and not misleading to the best of my knowledge;
   (b) I have received no guarantees or assurances that my application will be approved by the Queensland Government;
3. acknowledge that if my application is successful, I will be bound by the Smart Futures Fellowships Financial Incentive Terms and Conditions (version 2011-2012), a copy of which was available on the Department's website when I completed this application;
4. agree that when this declaration is signed by the Sponsoring Organisation, referred to in section 8 of this Application, and the Department's delegated officer, a legally binding agreement will exist between myself, the Sponsoring Organisation and the State of Queensland (represented by the Department) consisting of the following:
   (a) this Application, and
   (b) the Smart Futures Fellowships Financial Incentive Terms and Conditions (version 2011-2012).

SIGNED for and on behalf of:

the **Applicant**:

……..	……..	……
applicant's signature	*applicant's name*	*date*

in the presence of …… ……..….

name of witness *signature of witness*

We, the Sponsoring Organisation referred to in section 8 of this Application, agree that when this declaration is signed by the Applicant, referred to in section 2 of this Application, and the Department's delegated officer, a legally binding agreement will exist between, the Sponsoring Organisation, the Applicant and the State of Queensland (represented by the Department) consisting of the following:

(a) this Application, and

(b) the Smart Futures Fellowships Financial Incentive Terms and Conditions (version 2011-2012).

SIGNED for and on behalf of:

the **Sponsoring Organisation**:

……..	……..	……
sponsoring organisation's signature	*representative's name*	*date*

in the presence of …… ……..….

name of witness *signature of witness*

The following section will be completed if this application for a Smart Futures Fellowship is successful. Once approved and signed by the delegated departmental officer a legally binding agreement will be created between the Applicant, the Sponsoring Organisation and the State of Queensland (represented by the Department), such agreement consisting of this Application and the Smart Futures Fellowships Financial Incentive Terms and Conditions (version 2011-2012).

SIGNED for and on behalf of the State of Queensland through the **Department of Employment, Economic Development and Innovation** (ABN: 24 830 236 406) for the provision of approved Smart Futures Fellowship funding of up to $180,000 (excluding GST) over three years for early career fellowships or $360,000 (excluding GST) over three years for mid-career fellowships, as approved by the delegated authority on ……..*(the Department's officer to insert the date of approval),* and subject to the terms of this Application *and* the Smart Futures Fellowships Financial Incentive Terms and Conditions (version 2011-2012)*.*

……..	……..	……
signature of delegated representative	*representative's name*	*date*

in the presence of

…….	…….
name of witness	*signature of witness*

19. Checklist	
Have you completed all sections of the application?	■ Yes ☐ No
Do you have **matched cash funding** from your sponsoring organisations?	■ Yes ☐ No
Have you attached **signed letters of support** from your sponsor and all co-sponsors clearly indicating the levels of **cash contributions** to your proposed fellowship?	■ Yes ☐ No
Have you attached a **certified true copy of your PhD**, or of the official academic transcript that includes your awards and conferral dates?	■ Yes ☐ No
Have you and your sponsor **signed the declaration** (section 18)?	■ Yes ☐ No
Have you submitted the following **copies of the application** and supporting documentation: • one unbound, single-sided original (clipped, not stapled) • five spiral bound copies • one electronic version saved to CD	■ Yes ☐ No
If successful with this application, please note that you will subsequently be asked to complete Annexure 1 to this document by: • confirming or revising the research milestones provided in this application; • confirming the date upon which you will commence your research program; and • authorising the Department of Employment, Economic Development and Innovation to incorporate the above information (and any supporting documentation) as part of this application for a Smart Futures Fellowship.	■ Yes ☐ No
Please do **not** attach your curriculum vitae.	

This Annexure has been provided for reference purposes only and does not need to be completed as part of the initial application process. You will only be required to submit this information if your initial application is successful, as referred to in section 20.

ANNEXURE 1

With reference to my application for a Smart Futures Fellowship,

I, *[insert name]*, (the applicant) :

1. confirm that I will commence the research program outlined in my application for a Smart Futures Fellowship on *[insert fellowship commencement date];*
2. confirm that the fellowship research milestones outlined in section 12.4 of my Smart Futures Fellowships application:
   a. are correct; or
   b. have been revised and I attach the amended fellowship research milestones to this Annexure; (delete whichever is not applicable), and
3. authorise the Department of Employment, Economic Development and Innovation to incorporate this signed Annexure 1, and supporting documentation, as part of my application for a Smart Futures Fellowship.

SIGNED for and on behalf of:

the **Applicant**:

…….	…….	…….
applicant's signature	*applicant's name*	*date*

For reference only