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REDUCING ENERGY CONSUMPTION: INVESTIGATING SOLAR THERMAL HEAT DEFLECTION INNOVATIVE TECHNOLOGY TO REDUCE AIR CONDITIONING LOAD AT AIRPORTS – A TECHNO-ECONOMIC ASSESSMENT.

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Abstract

Air conditioning is a significant energy user in buildings in South Africa. Airports have large, centralized air conditioning systems for their terminal buildings which contribute around 20 % of the airport's energy consumption. Air conditioning systems are sized according to the cooling or heating demand as appropriate. Air conditioning systems not only cost a lot in energy consumption but also in maintenance which over a 20 to 25-year lifespan can make a significant impact on the environment. Designing air conditioning systems to be as efficient as possible in operations is one way of reducing the cost and environmental footprint of air conditioning systems. Another way is to reduce the cooling and heating demand passively. Insulation is effective in resisting heat gain from the environment, but most traditional materials of insulation require maintenance to ensure its effectiveness. Solar heat gain through the roof of buildings is a major contributor to the cooling demand and finding a way to significantly reduce this component will allow for a smaller air conditioning system to be adopted or allow existing air conditioning systems to supply a larger area. This paper presents an investigation into the adoption of a maintenance-free solar thermal heat deflective innovative technology that deflects 85 % to 95 % heat gain to reduce air conditioning energy consumption in airport terminal buildings in South Africa and provides a technical and economic assessment (or techno-economic assessment).

Keywords: Techno-economic assessments, reducing energy consumption in air conditioning systems, heat deflective coatings that save energy, passive cooling techniques for airport buildings

Introduction

The sizing of air conditioning systems satisfies cooling demand brought about by heat gains such as solar heat gain, people, equipment, artificial lighting, etc. (Fig. 1 and Table 1). There are various passive cooling techniques available that reduce the energy consumption of air conditioning systems. These passive cooling techniques include low overhangs to shade large windows and glass facades, the use of double glazing or low emissivity glass, the adoption of insulation, etc.

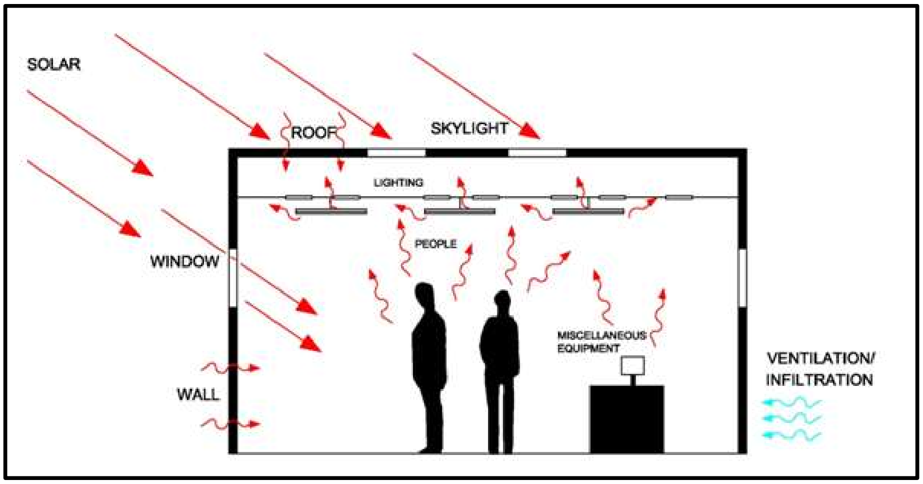

Figure 1: Various heat gains in a building [2]

Table 1: Internal and external heat gains [2]

External heat gains	Internal heat gains
Roofs/walls – conduction	Artificial lighting
Roofs/walls – radiation	Equipment and electronics
Skylights/windows – conduction	People
Skylights/windows – radiation	
Ventilation/infiltration	

Passive cooling techniques are very useful and are the first step of planning before the size of an air conditioning system can be chosen as it serves to reduce the size of an air conditioning system. This saves on capital costs and the cost of energy consumption, and, by implication, can reduce the related carbon footprint. Reducing energy consumption in air conditioning systems is a key focus for airports in South Africa as their contribution to electricity consumption is between 20 % to 30 % [1] of the total electricity consumption.

Even more effective in reducing the size and energy consumption of an air conditioning system is the elimination of components of heat gain such as solar heat gain through the roof of a building. The solar thermal heat deflection innovative technology investigated in this paper can deflect between 85 % to 95 % of the solar heat gain on the surface that it is applied to. Solar heat gain through the roof contributes between 25 % to 35 % of the heat load of an air conditioning system based on the climate of the geographical region, the architecture and material of construction of the roof, and insulation materials if any.

Traditional insulation is cost-effective for smaller spaces. However, as the roof area increases, the installation and maintenance cost of insulation versus the overall benefit of reducing the air conditioning load reaches a point where it is not feasible (Fig. 2). Traditional forms of insulation work by typically slowing down the heat ingress into the space by absorbing and retaining the heat within itself over a period of time. Thus, one can argue that the heat eventually reaches the space, however at a much slower rate (Fig. 3).

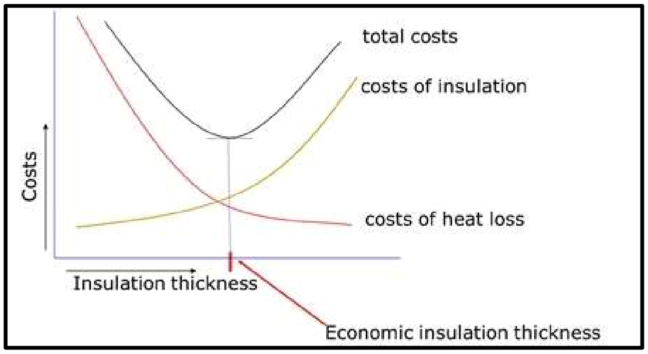

Figure 2: Typical economics curves of traditional insulation materials [3]

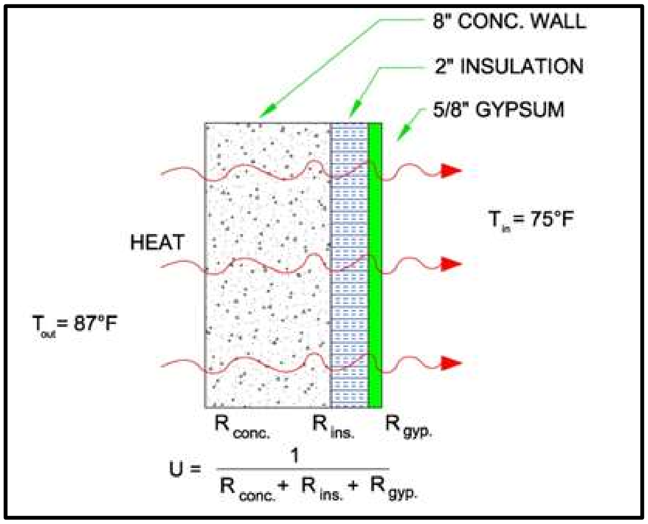

Figure 3: Traditional insulation thermal conductivity and heat resistance relationships [2]

When completing heat load calculations, the time lag factor is key. When the sun shines upon a wall face early in the morning, although the wall does experience a heat load, the amount of heat load experienced in the building at that time is minimal. This is due to the thermal mass of the wall. Thermal mass is also known as heat capacity and is defined as the ability of a material to absorb heat. The radiation from the sun onto the building and the time it takes for the heat to transmit through the materials must be considered. To calculate the total effect of the difference between the indoor and outdoor temperature, the effect of the solar radiation on the walls and roofs, and the time factor due to the heat storage of the roof/wall material, the engineer usually uses the Cooling Load Temperature Difference or CLTD. [2] The CLTD method uses the following equation to calculate heat ingress into the space:

$Q = U \times A \times (T_{outdoor} - T_{indoor})$………………………………………………...……Equation (1)

The solar thermal deflection innovative technology investigated in this paper is a ceramic-based insulation with two key innovations, namely, ceramic microspheres which are filled with inert gas. This coating, when applied to the surface exposed to solar radiation, does not allow the surface to heat load but rather deflects all the heat back to the surrounding environment. This means that there is no or negligible heat gain through that surface because it forms a thermal barrier. This innovative coating when applied to the roof surface also reduces the wear and tear on the roof due to expansion and contraction from solar radiation, leading to longer lifespans of the roof material and a better return on investment. This innovative coating was used initially by the National Aeronautics and Space Administration (NASA) to protect the front end of booster rockets. It deflected heat gain from wind resistance and engine exhaust.

This ceramic-based coating with inert gas-filled microspheres has found use in the insulation of furnaces in industry and is commercially available to be used on the roofs of buildings, on walls, and on any other surface that needs heat to be deflected. This insulation is investigated in this study for its use in deflecting solar heat gain for terminal building roofs for nine airports in South Africa owned and operated by Airports Company South Africa.

Airports Company South Africa is South Africa’s airport authority, owning and operating nine airports in South Africa, namely, O R Tambo International Airport (ORTIA) (Kempton Park, Gauteng), Cape Town International Airport (CTIA) (Western Cape), King Shaka International Airport (KSIA) (Durban, KwaZulu-Natal), Port Elizabeth International Airport (PEIA) (Eastern Cape), East London Airport (Eastern Cape), Bram Fischer International Airport (BFIA) (Bloemfontein, Free State), George Airport (Eastern Cape), Upington International Airport (Northern Cape) and Kimberley Airport (Northern Cape).

The key technical features that make ceramic-based solar thermal deflection material effective are microscopic, inert gas filled microspheres:

- Ceramic microspheres - the use of spheres increases the durability because a sphere is a very stable shape that can take abuse without cracking. The same cannot be said of irregularly shaped fillers that do not have strong internal structures. Once the ceramic microspheres link together to form a bond with the resin, they become even more durable against scratches, cracking, etc. and can withstand regular contact with industrial chemicals without breaking down.
- Inert gas or creation of vacuum – this makes heat transfer via conduction almost impossible.

The key factors and parameters for the ceramic-based solar thermal deflection coating to be adopted at airports are:

- Must be able to reduce the air conditioning load and thus electricity consumption and the airport’s carbon footprint by at least 25 %
- Needs to make financial sense to the business
- There should be no adverse effect on airport operations in respect of glare
- Class A fire rating and “0” flame and smoke
- It should have a manufacturer’s performance guarantee of at least 10 years
- It must be environmentally friendly, non-toxic and not contain any volatile organic compounds (VOCs)

1. Description of the technology

The ceramic-based coating referred to as “solar thermal deflective innovation technology” deflects about 95 % of the sun’s thermal energy contained in the infrared and ultraviolet rays. The ability of the ceramic-based coating to achieve this is through two key innovations within the coating which is applied as a paint. The coating contains ceramic microspheres wherein an inert gas or a vacuum exists.

Paint manufacturers blend the inert gas-filled ceramic microspheres (usually in a powder form) into the paints so that they form a heat-resistant film not allowing heat to pass through, but rather reflecting it back into the atmosphere. Fig. 4 shows a zoomed-in view of the shape and form of the microspheres. Every single ceramic microsphere is small and appears as a single grain of flour (slightly thicker than human hair).

Fig. 5 shows the shape and form of each ceramic microsphere (left), the paint application and the drying process depiction of how the insulating layer is formed (right). In effect, they are microscopic hollow vacuum sphere that deflects heat and reduces the transfer of sound.

When mixed into paint, the painted surface dries to a tightly packed layer of hard, hollow "microspheres", the tightly packed film reflects and dissipates heat by minimizing the path for the transfer of heat. The ceramics are able to reflect, refract and block heat radiation (loss or gain) and dissipate heat rapidly preventing heat transfer through the coating with as much as 90 % of solar infrared rays and 85 % of ultraviolet rays being radiated back into the atmosphere.

Figure 1: Insulating additive form – tiny ceramic inert gas filled microspheres [4]

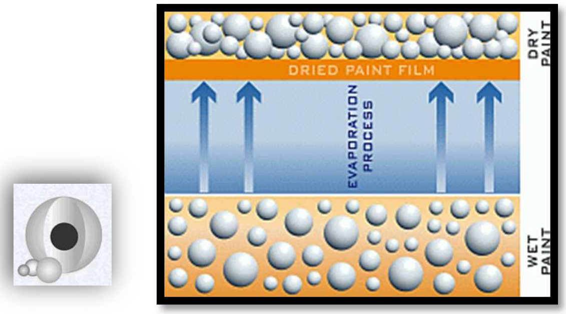

Figure 2: Form of the tiny microsphere (left) Typical paint application and drying process (right) [5]

The technology is available as a white powder additive to be mixed with any type and colour of paint to achieve the insulating effect. The paint itself together with the ceramic inert gas-filled (or vacuumed) microspheres can be bought from paint manufacturers.

2. Assessment of technology maturity

The ceramic inert gas-filled microspheres were invented in the course of searching for an insulating method for solid rocket boosters that experienced immense heat generated by wind resistance and engine exhaust during the launch of a space shuttle. Initial attempts at a solution for this problem were costly or had very accurate chemical processes, that, if they went out of parameters, became ineffective. To protect the solid rocket boosters, engineers at Marshall Space Flight Center in the 1980s developed a spray-on insulating process that was applied to the boosters' forward assembly, systems tunnel covers, and aft skirt. The materials were costly, and if the application was interrupted or not completed within the five-hour window, the batch was lost. In addition, the strength of the material was difficult to regulate, so it often chipped off during flight and splashdown (when the reusable boosters were dropped into the sea). Another disadvantage was that two of the nine ingredients were harmful to the environment. [5][6]

Through a Space Act Agreement in 1993, Marshall partnered with the United Technologies subsidiary, USBI, of Huntsville, Alabama, to develop an alternative to the old insulating spray. Using Marshall-developed convergent spray technology, they atomized epoxy and different filler materials to create an environmentally friendly ablative insulation material. The material, Marshall Convergent Coating-1 (MCC-1) consisted of 8 % hollow spherical glass, 9 % cork, and 83 % epoxy. The materials were mixed at the time of application, at the point of release from a spray gun, which eliminated the problem of batches being ruined from interruptions and delays. The insulating paint was first flight tested in 1996 on the STS-79 mission and was successful. It has been employed on all subsequent shuttle flights, with virtually no observed missing or chipped paint on the spent boosters during post-flight inspections. [5][6]

David Page, a founder of Tech Traders Inc., of Merritt Island, Florida, sought assistance developing coatings and paints that create a useful thermal reflectance. NASA made available technical assistance to small businesses. After a year of collaboration with NASA as well as additional testing with Dr. Heinz Poppendiek of the San Diego-based Geoscience Ltd., the product was ready for market. The San Diego-based Geoscience Ltd is a research and development firm specializing in heat transfer, fluid flow, mass transfer, micrometeorology, biophysics, engineering design, system fabrication, product evaluation, and the measurement of thermal, mechanical, and fluid properties. [5][6]

The insulating materials reduce heat transfer by reflecting heat away from the painted surface by forming a heat-blocking radiant barrier on the surface. The secret behind the product they called "Insuladd" is the unique propriety process that applies a coating to the microscopic inert gas-filled ceramic microspheres that make up Insuladd. When the paint dries, it forms the radiant heat barrier, turning ordinary house paint into heat-reflecting thermal paint. The insulating materials reduce heat transfer by reflecting heat away from the painted surface by forming a heat-blocking radiant barrier on the surface that is painted. [5][6]

The product works with all types of paints and coatings and will not change the coverage rate, application, or adhesion of the paint. It can be used on walls, roofs, ceilings, air-conditioning ducts, steam pipes and fittings, and is particularly well-suited for use on metal buildings, cold storage facilities such as walk-in coolers and freezers, and mobile or modular homes. [5][6]

Following this, many paint manufacturers have created their brands from the two main technology breakthroughs, i.e., ceramic inert gas fill microspheres. According to some paint manufacturers, the microspheres insulating ceramic additive have compressive strengths up to 41 MPa (6 000 psi), a softening point of about 1800 °C, and they are chemical resistant, with low thermal conductivity of 0.1 W/m/°C. The addition of ceramics to any material provides improved fire resistance, protection of coated surfaces from harmful UV rays, repulsion of chewing insects and increased durability of the coating due to the hard ceramic finish. Ceramic-filled paint is easier to clean and lasts far longer than conventional paint pigments. [5][6]

3. Cost-benefit analysis

This section summarizes the rationale for the technology selection and presents the feasibility study should the ceramic-based insulation be adopted by the airports.

3.1 Rationale for the technology selection

Reducing energy consumption towards carbon neutrality in electricity consumption has two major focuses, i.e., lighting energy consumption and air conditioning energy consumption reduction. [1] To reduce energy consumption from air conditioning systems, many initiatives were considered for implementation. An opportunity of energy conservation through the reduction of solar heat gain through the terminal building roofs was highlighted.

3.2 Economic Analysis Results and Benefits

A case study was captured by the Tucson airport that adopted the Smartcoat SUPER THERM$^{®}$ brand of ceramic-based thermal deflection coating. Table 2 contains the parameters and air conditioning energy savings. Fig. 3 shows the full surface area that constituted the project and the energy savings. Fig. 4 shows a progress snapshot.

Table 2: Tucson airport summary of the cost of the ceramic based paint and the energy savings

Tucson airport ceramic based painted roof area (sqft)	Cost of the project per square foot in 2008 (US$/sqft)	Conversion of sqft to sqm (sqm)	Converted to US$/sqm	price per square meter in 2018 – using compounded escalation (R/sqm)	Total savings in US$ per month	% Energy Savings on the HVAC system

374 804	2.1	34 820.41	22.604	584.94	$22 144 (22 % reduction)	40 % (A/C portion of the total utility being 55 %)

The total roof area of the terminal is 374 804 ft^2 applied at US$2.10 /ft^2 is US$787 088. With a cost reduction of US$22 144 /month, this results in a return within 35.54 months. With the total utility savings of $22 144 (22 %) in August for the total facility and the air conditioning portion of the total utility being 55 %, this relates to a 40 % savings in air conditioning operational cost. The savings are beyond the air conditioning running cost; the units cycle more giving longer life and requiring less maintenance work and less tonnage to take care of the main terminal and wings. A key point is that the 22 % savings for the airport were on the total energy bill (lighting, elevators, food facilities, etc). This simply means that the SUPER THERM® made a 40 % reduction in the air conditioning costs The air conditioning portion of a total energy bill is 55 % which when calculated on the 22 % savings of the total relates to a 40 % savings in pure air conditioning costs. [7]

Figure 3: Areas painted with ceramic based thermal deflective paint [7]

Figure 4: Project in progress – Tucson Airport application of the ceramic based thermal deflection paint [7]

For the purposes of the ACSA airports' economic analysis, a conservative 25 % energy reduction in current HVAC energy consumption was used. Table 3 contains each airport's HVAC energy consumption estimation (at 25% of their total energy consumption) and the respective roof surface areas to be coated with the ceramic-based coating.

Table 3: ACSA airports HVAC Energy consumption and roof surface areas to be covered

Airport	HVAC Annual Energy Consumption (kWhs)	Roof surface area (m^2)
OR Tambo International Airport	7 255 943.21	100 000
Cape Town International Airport	4 294 822.38	40 000
King Shaka International Airport	2 116 495.00	32 000
Port Elizabeth International Airport	465 320.31	2 000
East London Airport	264 268.75	3 000
Bram Fischer International Airport	202 713.25	3 000
George Airport	123 577.56	4 000
Upington International Airport	48 904.94	2 500
Kimberley Airport	20 227.38	1 800

The economic analysis presented in this study was performed during the period 1 April 2018 to 31 March 2019, by the economic modelling department of Airports Company South Africa.

The economic model yields the net present value (NPV), internal rate of return (IRR), the nominal payback period and the profitability index (PI). The IRR is compared to ACSA's 11.5 % weighted average cost of capital (WACC) rate (2018) to determine economic feasibility. When the NPV is zero or positive is it an investment that pays itself off during its economic lifespan. The NPV equation used in the economic model is given below (Equation 2). The IRR is the return (i in the equation below) when the NPV is zero. When the IRR is greater than the discount rate (or the WACC rate), then the investment is feasible for the business. The payback period is the amount of time required for cash inflows generated by a project to offset its initial cash outflow. The payback should be reasonably within the economic lifespan of the investment. The PI (given in Equation 3) shows the financial attractiveness of the proposed project and is the ratio of the sum of the present value of the future expected cash flows to the initial investment amount. A PI greater than 1.0 is deemed to be a good investment, with higher values corresponding to more attractive projects.

$$NPV = \sum_{t=0}^{T} \frac{R_t}{(1+i)^t}$$

………………..……………………………………………………Equation (2)

Where: R_t = net cash inflows – outflows during a single period t

i = discount rate or return that could be earned

t = number of time periods

$$PI = \frac{PV\ of\ future\ cash\ flows}{Initial\ Investment}$$

……………………………………………………………………Equation (3)

The summarized economic analysis presented in the next section uses the above figures in economic models.

(a) Summary

Table 4 to Table 12 presents the results of economic modelling for each airport considering their adoption of ceramic based thermal deflection paint.

Table 4: OR Tambo International Airport summarized economic analysis

Inputs		Output	
Roof surface area (m^2)	100 000	End of job cost	ZAR 61.48m
Capital cost (2018 basis)	ZAR 58.5m	Net present value	ZAR 17.99m
Electricity kWh saving	7 255 943.21	Internal rate of return	18.1 %

Annual electricity cost saving (ZAR 1.47 /kWh)	ZAR 10.67m	Nominal payback period	4 years
Electricity escalation	5.1 %		
Beneficial operation	2020		
Construction period	1 year		
Corporate tax	28 %		
Economic lifespan	10 years		
Degradation	0.8 % per annum		
Operations and maintenance cost	ZAR 0		

Table 5: Cape Town International Airport summarized economic analysis

Inputs		**Output**	
Roof surface area (m^2)	40 000	End of job cost	ZAR 24.59m
Capital cost (2018 basis)	ZAR 23.4m	Net present value	ZAR 19.52m
Electricity kWh saving	4 294 822.38	Internal rate of return	27.8 %
Annual electricity cost saving (ZAR 1.47 /kWh)	ZAR 6.31m	Nominal payback period	3 years
Electricity escalation	5.1 %		
Beneficial operation	2020		
Construction period	1 year		
Corporate tax	28 %		
Economic lifespan	10 years		
Degradation	0.8 % per annum		
Operations and maintenance cost	ZAR 0		

Table 6: King Shaka International Airport summarized economic analysis

Inputs		**Output**	
Roof surface area (m^2)	32 000	End of job cost	ZAR 19.67m
Capital cost (2018 basis)	ZAR 18.72m	Net present value	ZAR 1.64m
Electricity kWh saving	2 116 495.00	Internal rate of return	13.5 %

Annual electricity cost saving (ZAR 1.29 /kWh)	ZAR 2.73m	Nominal payback period	5 years
Electricity escalation	5.1 %		
Beneficial operation	2020		
Construction period	1 year		
Corporate tax	28 %		
Economic lifespan	10 years		
Degradation	0.8 % per annum		
Operations and maintenance cost	ZAR 0		

Table 7: Port Elizabeth International Airport summarized economic analysis

Inputs		Output	
Roof Surface area (m^2)	2 000	End of job cost	ZAR 1.23m
Capital cost (2018 basis)	ZAR 1.17m	Net present value	ZAR 2.69m
Electricity kWh saving	465 320.31	Internal rate of return	50.7 %
Annual electricity cost saving (ZAR 1.29 /kWh)	ZAR 600 263	Nominal payback period	2 years
Electricity escalation	5.1 %		
Beneficial operation	2020		
Construction period	1 year		
Corporate tax	28 %		
Economic lifespan	10 years		
Degradation	0.8 % per annum		
Operations and maintenance cost	ZAR 0		

Table 8: East London Airport summarized economic analysis

Inputs		Output	
Roof surface area (m^2)	3 000	End of job cost	ZAR 1.84m
Capital cost (2018 basis)	ZAR 1.75m	Net Present Value	-ZAR 0.43m
Electricity kWh saving	264 268.75	Internal rate of return	5.4 %

Annual electricity cost saving (ZAR 0.60 /kWh)	ZAR 158 561	Nominal payback period	7 years
Electricity escalation	5.1 %		
Beneficial operation	2020		
Construction period	1 year		
Corporate tax	28 %		
Economic lifespan	10 years		
Degradation	0.8 % per annum		
Operations and maintenance cost	ZAR 0		

Table 9: Bram Fischer International Airport summarized economic analysis

Inputs		**Output**	
Roof surface area (m^2)	3 000	End of job cost	ZAR 1.84m
Capital cost (2018 basis)	ZAR 1.75m	Net present value	ZAR 0.27m
Electricity kWh saving	202 713.25	Internal rate of return	14.9 %
Annual electricity cost saving (ZAR 1.36 /kWh)	ZAR 275 690	Nominal payback period	5 years
Electricity escalation	5.1 %		
Beneficial operation	2020		
Construction period	1 year		
Corporate tax	28 %		
Economic lifespan	10 years		
Degradation	0.8 % per annum		
Operations and maintenance cost	ZAR 0		

Table 10: George Airport summarized economic analysis

Inputs		**Output**	
Roof surface area (m^2)	4 000	End of job cost	ZAR 2.46m
Capital cost (2018 basis)	ZAR 2.34m	Net present value	-ZAR 1.5m
Electricity kWh saving	123 577.56	Internal rate of return	N/A

Annual electricity cost saving (ZAR 0.68 /kWh)	ZAR 84 032	Nominal payback period	No payback
Electricity escalation	5.1 %		
Beneficial operation	2020		
Construction period	1 year		
Corporate tax	28 %		
Economic lifespan	10 years		
Degradation	0.8 % per annum		
Operations and maintenance cost	ZAR 0		

Table 11: Upington International Airport summarized economic analysis

Inputs		**Output**	
Roof surface area (m^2)	2 500	End of job cost	ZAR 1.54m
Capital cost (2018 basis)	ZAR 1.46m	Net present value	-ZAR 0.93m
Electricity kWh saving	48 904.94	Internal rate of return	N/A
Annual electricity cost saving (ZAR 1.10 /kWh)	ZAR 53 795	Nominal payback period	No payback
Electricity escalation	5.1 %		
Beneficial operation	2020		
Construction period	1 year		
Corporate tax	28 %		
Economic lifespan	10 years		
Degradation	0.8 % per annum		
Operations and maintenance cost	ZAR 0		

Table 12: Kimberley Airport summarized economic analysis

Inputs		**Output**	
Roof surface area (m^2)	1 800	End of job cost	ZAR 1.11m
Capital cost (2018 basis)	ZAR 1.05m	Net present value	-ZAR 0.46m
Electricity kWh saving	20 227.38	Internal rate of return	N/A

Annual electricity cost saving (ZAR 1.56 /kWh)	ZAR 31 554	Nominal payback period	No payback
Electricity escalation	5.1 %		
Beneficial operation	2020		
Construction period	1 year		
Corporate tax	28 %		
Economic lifespan	10 years		
Degradation	0.8 % per annum		
Operations and maintenance cost	ZAR 0		

From the economic analyses, one can see that for five airports implementation is currently feasible, i.e., ORTA, CTIA, KSIA, PEIA and BFIA. Implementation at the remaining airports is unfeasible based on the parameters used.

(b) Sensitivity Analysis

For the sensitivity analysis, the airports that show feasibility need to be looked at for a change in the parameters that made the business case for the airports. The parameters that made the airports implementation feasible is the energy savings (kWh) together with the electricity tariff.

The effect of the electricity tariff in the economic analysis conducted for BFIA and East London Airport can be clearly seen. Their implementation scale is exactly the same, and their energy savings similar, but the significant difference is the electricity tariff (ZAR 1.36 /kWh versus ZAR 0.60 /kWh).

Looking at PEIA and Kimberley Airport, their electricity tariffs are ZAR 1.29 /kWh and ZAR 1.56 /kWh respectively, and their implementation scale are almost the same, but the energy savings associated with implementation is what made PEIA's implementation feasible and Kimberley Airport's implementation not. PEIA's energy savings are more than 20 times those of Kimberley Airport's energy savings. PEIA has a central air conditioning system producing chilled water for the airport's cooling needs, whereas Kimberley Airport has a distributed system of split units, wall mounted and cassette units.

Another factor to consider is the climate at each of the sites, their roof material type (concrete or metal-based) and the type of air conditioning system meeting the air conditioning need. These factors directly influence the energy consumption for air conditioning. If, by measurement of the air conditioning electricity consumption, the expected energy savings are more for each airport, the economics may be revised accordingly.

4. Technology Risk Assessment

The ceramic-based thermal deflective coating is based on two revolutionary technological break-throughs, namely, ceramic microspheres and the incorporation of an inert gas which together provide structural rigidity, ensuring that the material is able to stand the abuse of impact, temperatures and industrial chemicals and heat deflection by offering almost no medium for heat transfer.

Most of the paint industry is now incorporating these two technologies into their products with some paint industries offering just these two technologies in a powder product to be added to any type of and colour of paint. While using the powder product may seem more convenient and self-applying this could save on costs, however, the risk is that should there arise an issue with the paint mixture once applied, the coating flakes/breaks off, or if the desired insulation effect is not achieved, or the life of the product is not reached within the economic life upon which the project was approved, there will be no way to rectify this in order to ensure that the financial investment is not wasted.

For this reason, it is best that one ensures the following:

- The paint is purchased from a SABS approved manufacturer/supplier.
- The product is applied by the manufacturer or a manufacturer approved contractor that will preserve the warranties and guarantees that come with the product.
- The product should be performance guaranteed (the minimum agreement is that the HVAC system electricity consumption is reduced by at least 25 %) and the guarantee on the lifespan should be at least 10 years (or as per the calculation parameters on feasible economic lifespan).
- As an added convenience to ensure that the investment is protected in terms of guaranteed performance, the paint should contain both the microsphere and inert gas or vacuum technological features.
- The paint should ensure that there is no glare to pilots – a preferable colour is dove-grey rather than white. The microsphere and inert gas technologies are not dependent on colour for their thermal resistance function.
- The ceramic coating must have a Class A fire rating and “0” flame and smoke.
- It must be environmentally friendly, non-toxic and not contain any volatile organic compounds (VOCs).

5. Airport’s integration strategy

The airports should adopt this paint as a turnkey solution with guarantees and warranties in place as described in the technology risk assessment section. The current airport’s terminal building roofs should be painted with this paint (exposed metal surfaces are preferable to concrete roofs which already provide enough thermal resistance). All new terminal buildings or terminal building roof refurbishment projects should incorporate this coating within the project. This should also be considered for projects involving refurbishing or resizing a central HVAC or air conditioning system for a facility as a passive cooling technique. A measurement and verification exercise must be undertaken to ensure that the performance guarantee given by the manufacturer is tested and tracked.

6. Strategic fit of the solar thermal deflection innovative technology

The solar thermal deflective innovation coating gives an annual cost saving of ZAR 20.6m and results in 6.25 % saving in electricity consumption across five airports in South Africa (Table 13).

Table 13: Cost savings and impact of solar thermal deflection innovation on the carbon neutrality journey

Airport	**Annual cost savings in ZAR million (expressed in 2018 terms)**	**Impact of the solar thermal deflection innovative technology project to the airport's carbon neutrality goal**
OR Tambo International	10.67	6.25 %
Cape Town International	6.31	6.25 %
King Shaka International	2.73	6.25 %
Port Elizabeth International	0.600	6.25 %
Bram Fischer International	0.275	6.25 %
Total savings (ZAR in 2018 terms)	**20.6**	

Conclusion

The solar thermal heat deflection innovative technology investigated in this paper uses ceramic-based, inert gas fill microspheres to form a heat barrier that deflects heat which does not allow the surface that it is applied to, to heat load. The five airports that showed the solar thermal heat deflective innovation technology feasible for implementation are ORTIA, CTIA, KSIA, PEIA and BFIA. The technology could be implemented for ORTIA, CTIA and KSIA by the airports' building maintenance departments and for PEIA and BFIA, this implementation could be executed by an external service provider. Should this option be implemented, appropriate measurement and verification exercises should be conducted to ensure that performance guarantees obtained from the manufacturer are tracked. Such a technology would contribute to an average of 6.25 % reduction in electricity consumption and carbon emissions across the selected airports, with a potential annual electricity consumption saving of ZAR 20.6m.

References

[1] Joseph, J., Inambao, F.L., "Energy consumption and energy efficiency of airports: A case study of airports in South Africa", International Journal of Mechanical and Production Engineering Research and Development, Volume 11, Issue 2, April 2021.

[2] Engineering Pro Guides, "Heating/cooling loads for the mechanical HVAC & refrigeration PE exam", https://www.engproguides.com/hvac-heating-cooling-loads.html, accessed 27/06/2021.

[3] Committee Industrial Insulation Standards, “Minimum total cost method”, https://www.cini.nl/en/knowledge-center/cinicalc-tool/insulation-thickness/, 2014, accessed 27/06/2021.

[4] Alibaba.com https://www.alibaba.com/product-detail/refractory-material-insulation-cenospheres-hollow-ceramic_60721479525.html?spm=a2700.pc_countrysearch.main07.1.3e176a31T5Ca0q, accessed 16/03/2019

[5] Hy-Tech Thermal Solutions, “ThermaCels™ ceramic paint additive makes any paint insulate”, http://www.hytechsales.com/ceramics/, accessed 17/03/2019.

[6] National Aeronautics and Space Administration, “Insulating paint powder turns every color 'green'”, https://www.nasa.gov/topics/nasalife/green_paint.html, accessed 17/03/2019.

[7] Wilt, C., “Energy Audit and Report: Tucson Airport 374804 sq.ft. of roofing coated with the SUPER BASE(HS) / SUPER THERM® SYSTEM”, Tucson Airport facilities manager, 2009.