Can Archive Film Stores in the Global South Achieve Net Zero and Reliable Energy?

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Abstract

Countries are increasingly expected to secure sustainable and reliable energy for all. This is however challenging in developing countries, which often suffer from inadequate infrastructure. Focusing on film stores, such a poor supply of energy can prevent them from preserving the cultural heritage related to photographic films. Hence, this paper tests various service-side and construction-side solutions, in order to investigate the potential of film stores to attain net zero and reliable energy, and support decarbonisation and film preservation. An exemplar film store is modelled in different locations in the Global South. The predicted trade-offs between energy use and the usable life of films are presented, providing useful design guidance.

Key Innovations

- Film stores in the Global South can reap net zero, subject to a hot and humid climate.
- Phase change materials, insulating concrete form and PVs can help film stores attain net zero.

Practical Implications

This paper provides design practitioners with guidance on designing archive film stores with a focus on countries in the Global South, which lack relevant design examples.

Introduction

The need for universal access to modern, sustainable and reliable energy is highly acknowledged in the Sustainable Development Goals (SDGs) introduced by the United Nations (UN 2015). In more detail, SDG 7 calls for the expansion of existing infrastructure as well as the upgrade of technology for securing clean energy for everyone, this implying the expected increase in the share of renewable energy in the global energy mix. Renewable energy is key to minimising carbon dioxide (CO_2) emissions and thus dealing with climate emergency (LETI 2020). At the same time, by reducing reliance on fossil fuels, it can disburden countries of the costs that accompany fossil fuel imports, thus also resulting in considerable economic benefits.

Special attention should be paid to developing countries, where the commonly observed lack of infrastructure and technologies prevents the adequate supply of energy and thus the aspired achievement of an equitable and universal implementation of sustainable development (UN 2015). As an example, according to the Energy Progress Report (The World Bank 2018), in 2017, the percentage of total final energy consumption that was covered by renewable energy in Yemen was less than 5%, whereas only 62% of the population had access to electricity. Power outages are another common phenomenon, with their number over a typical month being reported to be equal to almost 40 (The World Bank 2013). To get a better feel for the differences in the provision of electricity services between developing and developed countries, the corresponding numbers for Sweden are: 52% of energy consumption was covered by renewable energy in 2017, with 100% of the population having access to electricity (The World Bank 2018), and no power outages being reported (The World Bank 2014).

But why does reliable energy matter? Firstly, as electricity use will be rising (i.e. due to the extensive electrification of both transport and heating), grid instability will prevent countries from powering their economies (UN 2020). In addition to any economic implications, power outages can increase CO_2 emissions and hence detrimentally affect the environment due to the diesel-fuelled back-up generators that are typically used in such instances (Farquharson *et al.* 2018). Finally, the associated disruption of the smooth operation of buildings can have a negative impact on their indoor conditions and therefore on the health and quality of life of their occupants (Baniassadi *et al.* 2018).

Focusing on buildings which store photographic films, the disruption of their smooth operation and hence the change in their indoor conditions can also significantly affect the lifespan of films. In particular, an inadequate preservation of films, such as storing them at high temperatures and/or humidity levels, can lead to the decomposition of the film emulsion and consequently the loss of information in the image (Fossati 2018). Hence, reliable energy is critical in the case of film stores to ensure that films are constantly stored at the right conditions and are ultimately preserved over time. Despite the importance of indoor conditions in increasing the lifespan of films, there is a lack of relevant studies in the literature, mainly in the case of developing countries. Balancing film preservation and energy use is also under investigated, this being the focus of this study.

At the same time, there is an increasing need for countries to reduce their CO_2 emissions to meet national objectives. This will undoubtedly affect the design, construction and operation of buildings, which are claimed to be the largest (single) contributor to energy consumption and associated CO_2 emissions (European Commission 2019). The aim of achieving net zero emissions has already been included in the policy documents of several developed countries, such as New Zealand (New Zealand Government 2019) and the

UK (UK Government 2019). A few developing countries, such as Mongolia (Green Climate Fund 2019), have also expressed their interest in moving towards net zero. There is, however, a lack of initiatives in such countries (mainly due to financial reasons) and hence of practical examples, which necessitates the investigation of CO_2 mitigation in such settings (Wimbadi and Djalante 2020).

Hence, this paper investigates the potential of archive film stores to attain net zero and reliable energy and ultimately protect both their film stocks and the environment. There is a focus on developing countries in the Global South due to the aforementioned lack of examples (and therefore of design guidance), as well as the lack of infrastructure and grid stability which makes the need for immediate action more imperative in such settings. An additional argument for focusing on such countries is that these are more likely to face a lack of funding for covering running costs (which can be considerably high due to the need to store films at low temperatures), as well as aggressive climates that may further increase building energy consumption and hence running costs. Various service-side and construction-side solutions are thus tested to help archive film stores in such settings support the vision for a zero-carbon future, while preventing their films from degrading, at a minimum cost. The trade-off between energy consumption and the usable life of films is presented, in an effort to assist designers in making informed decisions when designing film stores.

Film preservation

Archive film stores aim to safeguard the cultural heritage of countries by protecting their photographic films from degrading. A film is a strip of celluloid (most commonly made of cellulose nitrate or acetate) coated with a layer of emulsion, on which images are imprinted. The lifespan of films is correlated with the conditions these are stored at, as high temperatures or humidity levels can result in the melting of the film emulsion, and consequently the loss of information in the imprinted image (Fossati 2018). High temperatures or humidity levels can also cause the decay of the (nitrate or acetate) film base (Figure 1), this greatly increasing the need for restoration or digitisation. Such a process may, however, be impractical due to the number of films and associated cost. At the same time, digitisation marks a shift in the culture of film heritage and the future role of film stores which is controversial, as physical films are considered to be part of the heritage story.

Figure 1: Degraded reels of film in Sri Lanka (Walsh et al. 2018).

The specification of the indoor conditions of archive film stores is hence key to managing the degradation of films, and ultimately extending their usable life. As suggested by the International Federation of Film Archives (FIAF) (Bowser and Kuiper 1980), typical conditions are:

- A temperature between -5℃ and 10℃.
- A relative humidity (RH) level between 20% and 50%.
- A minimum ventilation rate equal to 0.02 air changes per hour (ACH).

Although films may possibly decay in different ways, the 'Storage Calculator for Acetate' (IPI 2020a), developed by the Image Permanence Institute (IPI), can estimate the effect of indoor conditions on fresh and degraded acetate films, providing an indication of their life expectancy. In particular, inputs express the annual average temperature and RH films are stored at. Outputs express the number of years taken for *fresh acetate* to reach the onset of vinegar syndrome (A-D Strip level 1.5) and for *degraded acetate* (A-D Strip level 1.5) to reach poor condition (A-D Strip level 2). 'Vinegar syndrome' is used to signify the acetate film degradation that is caused by poor storage conditions – and is related to the chemical nature of cellulose acetate plastic materials (National Film Preservation Foundation 2010). Note that, although the symptoms of degradation may vary from one film type to another, both acetate and nitrate films can slowly decompose under the influence of heat and/or moisture, with the storage conditions that are good for acetate being also good for nitrate, and vice versa (Reilly 1993).

'A-D Strips' (IPI 2020b) are a tool, also developed by the IPI, to measure the extent of vinegar syndrome in acetate film collections and define their storage conditions. This is performed with the help of dye-coated paper strips that change colour when exposed to acetic acid vapour given off by degrading film. Colour varies from blue to yellow to reflect a film condition that varies from good to critical, as also captured by the A-D Strip level that varies from 0 to 3 (Table 1). Even though A-D Strips can give a feel for how much a film has degraded, the advice the tool offers on how films should be stored, is quite generic. That is, it does not provide specific guidance on the temperature and the RH level films should be stored at, nor does it define the effect of indoor conditions on energy demand, which is however important in view of a zero-carbon future.

Table 1: A-D Strip levels and their interpretation (adapted from IPI 2020b).

A-D Strip level	Film condition	Recommended storage conditions
0	**Good** (no deterioration)	Cool or cold storage
1	**Fair to good** (deterioration starting)	Cold storage
1.5	**Rapid decay starting** (point of decay)	Cold or frozen storage
2	**Poor** (actively degrading)	Frozen storage
3	**Critical** (shrinkage and warping)	Frozen storage

Solutions

Having on the one hand the vision for a zero-carbon future and on the other hand the importance of film preservation, different service-side and construction-side solutions are explored to help archive film stores achieve these goals. Such solutions are briefly described below – before they are applied to a case study building (see 'Method').

Starting with service-side solutions, *ground source heat pumps (GSHPs)* are becoming popular as we are moving towards electrification. These can be classified in ground-coupled, groundwater or surface water heat pumps, if they are using the ground, the subsurface water or the surface water respectively as a heat source and sink (Reda 2017). Due to the inherent uncertainty in the availability of water, this study focuses on ground-coupled heat pumps. These make use of vertical heat exchangers, which are typically installed at deep depths (45m to 150m), or horizontal heat exchangers, which are installed at shallow depths (1m to 3m). Such heat exchangers act as evaporators, if heating is provided, or as condensers, if cooling is provided, thus also lowering RH in the zone.

Variable air volume (VAV) systems are likewise becoming popular due to their increased – compared to conventional constant air volume (CAV) systems – energy efficiency. VAV systems control air temperature through varying the amount of air supplied. In particular, devices at zone level control the quantity of air supplied to the zone, in order to ensure that the supply air temperature remains relatively constant (Butcher 2005). The condenser within the chiller cools the hot refrigerant using either ambient air or water, this differentiating air-cooled chillers from water-cooled chillers. The latter are reported to be more efficient, with their performance being however dependent on climatic conditions such as RH. On the contrary, the performance of air-cooled chillers is not affected by RH, this making them a safer option in locations where RH is high.

Moving to construction-side solutions, exploiting *thermal mass* can positively affect the diurnal heating and cooling cycles of buildings. In particular, thermal mass can assist buildings in achieving a time lag between external and internal air temperatures, and ultimately stabilising their internal air temperature (de Saulles 2019). This is of great importance in the case of archive film stores in the Global South where the common phenomenon of power outages could detrimentally affect indoor conditions, and hence the lifespan of films. An *underground construction* could also assist buildings in passively controlling indoor air temperatures, due to the ability of earth to keep buildings cool during warm days, but also warm during cold nights (Khair-el-Din 1984).

Using *insulating concrete form (ICF)* is another passive strategy for regulating internal air temperatures by taking advantage of the thermal mass of concrete. ICF combines the structural capacity and thermal mass of (cast-in-place, reinforced) concrete, with the high thermal resistance of foam insulation boards (i.e. expanded polystyrene (EPS)). The overall construction is also airtight, hence resulting in considerable energy savings (Juhl 2012). If coupled with *phase change materials (PCMs)*, additional savings could be yielded thanks to the energy storage capacity of PCMs (Ling and Poon 2013). In more detail, PCMs are able to absorb or release latent heat during their phase transition, smoothing out temperature variations (Fleischer 2015).

Even though this is not an exhaustive list of service-side and construction-side solutions, they are solutions that are becoming popular on our way to decarbonisation – and to the achievement of SDG 7. In addition to improving the energy efficiency of buildings by applying such solutions, increasing their renewable energy generation is also vital for CO_2 mitigation (Swain and Karimu 2020). Scaling up renewables such as *photovoltaics (PVs)* on site can assist buildings in minimising the amount of energy they draw from the grid when its carbon intensity is high (especially when coupled with storage systems such as batteries), and hence contribute to the decarbonisation of both the built environment and the grid (Fosas *et al.* 2020).

Method

This study aims to investigate the potential of archive film stores in the Global South to achieve net zero and reliable energy, and ultimately protect both their film stocks and the environment. In this context, an exemplar archive film store was simulated in three locations that cover a gamut of climatic conditions (Figure 2): Katunayake, Sri Lanka (hot and humid); Ulaanbaatar, Mongolia (cold and dry); and Sanaa, Yemen (hot and dry). Sri Lanka experiences a negligible annual variation in external dry-bulb and dew-point temperatures, as the weather is consistently hot and humid. Mongolia demonstrates a remarkable variation in climatic conditions, as the external dry-bulb temperature varies from -30°C in winter, to 25°C in summer. Yemen also showcases an annual variation in climatic conditions – although this is less significant compared to Mongolia. In general, dew-point temperatures are much lower than dry-bulb temperatures, this suggesting low RH levels.

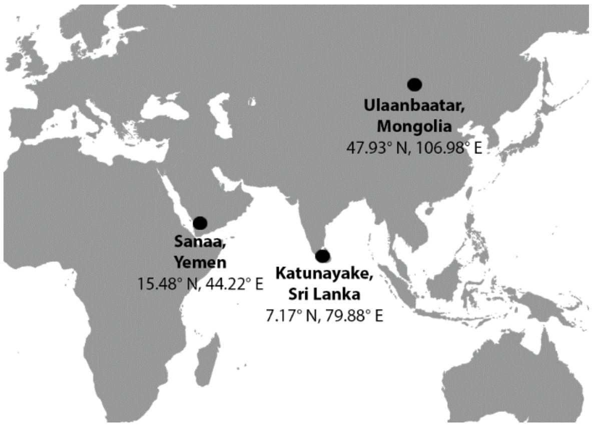

Figure 2: Details of the selected locations.

The thermal model of the film store (Figure 3) was built in DesignBuilder (DesignBuilder Software Ltd 2019), as this is a user-friendly modelling environment that enables the assessment of building performance using a detailed simulation engine (i.e. EnergyPlus). The film store has a floor area of 250m^2 (as measured from the centre lines of external walls). It consists of the entrance (in the North), main corridor and six zones where films are stored. Apart from the entrance door, the building has no openings.

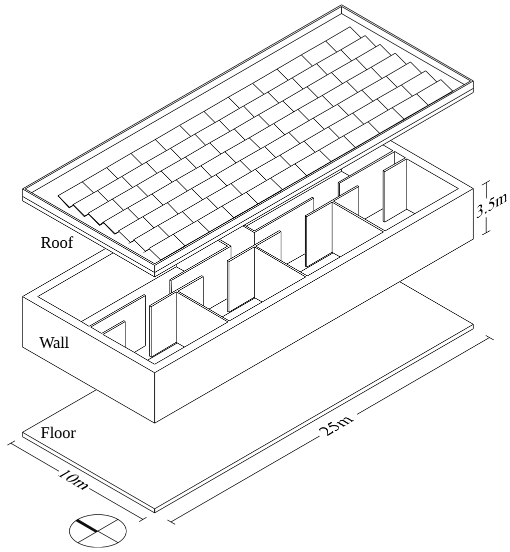

Figure 3: Exploded isometric of the modelled film store.

The service-side and construction-side solutions that were described under 'Solutions' were then tested with the help of the DesignBuilder model, with the aim of exploring the potential of the film store to achieve net zero energy while preventing films from degrading, in all three locations. In particular, two construction solutions (*ICF and PCM*, and *thermal mass*) were modelled in the case of two possible ground conditions (*underground* and *overground*), hence resulting in a total number of four construction solutions (per location). Note that, underground construction means that 3.5m deep earth covers East, South and West facades. The details of the construction solutions are summarised in Table 2 (see 'Appendix').

All four construction solutions were modelled under four scenarios, these representing plausible indoor conditions (that is, combinations of internal air temperatures and RH levels). The definition of indoor conditions was informed by the design guidelines that were described under 'Film preservation'. Scenarios thus include the following values (for temperature and RH respectively): upper limits (10°C and 50%); lower limits (-5°C and 20%); and their average values (2.5°C and 35%). A fourth scenario was defined to include the possibility of having no service-side solution, with indoor conditions thus varying from one location to another, since they are subject to climatic conditions. The details of the 16 simulations that were run in each location (48 in total) are summarised in Table 3 (see 'Appendix').

Concerning service-side solutions, the HVAC system that was selected in each location represents the most effective system for that location, according to the literature review and the experiments run in DesignBuilder. As discussed under 'Solutions', climatic conditions such as external air temperatures and RH levels can affect the effectiveness of HVAC systems. Having the aim to minimise energy usage whilst maintaining the defined conditions, the following systems were modelled in each location: Katunayake, Sri Lanka – *GSHP*; Ulaanbaatar, Mongolia – *VAV air-cooled chiller*; and Sanaa, Yemen – *VAV water-cooled chiller*. Systems are always on, in order to cool the zones and thus prevent films from degrading. A baseline ventilation rate of 0.02 ACH was considered (see 'Film preservation').

Electricity generation using *PV panels* was also explored, with the aim of achieving net zero, but also providing the film store with a greater reliability in the light of frequent power outages. The Astronergy Star II 365Wp PV module (ACOSolar 2020) was modelled in DesignBuilder. This has an efficiency of 18.9% and its dimensions are 1,954 x 990 x 40mm. The roof of the film store accommodates 84 south-facing modules (Figure 3). These were modelled as part of an electric load centre, whose electrical buss type is direct current (DC) with a 95% efficiency inverter. The latter collects the DC power which is produced by the PV modules and produces the alternating current (AC) power which is recorded as electricity production. The optimum slope angle for the modules was calculated with the help of the European Commission's PVGIS tool (2020), based on the latitude and longitude of each location (Figure 2).

Additional information on the selected methods and case study can be found in (King *et al.* 2021).

Results and Discussion

Energy consumption and generation

Figure 4 illustrates the annual energy consumption of the film store (normalised per conditioned floor area) across the solutions and scenarios (indoor conditions) described under 'Method', in all three locations in the Global South. The film store in Sri Lanka is associated with the highest value (5,027 kWh/m^2.yr), which occurs in the case of the ICF and PCM solution, as well as the lowest setpoint for air temperature and RH (-5°C and 20%, respectively). In the case of thermal mass, the corresponding value is 2,039 kWh/m^2.yr. Such a poor performance can be attributed to the climatic conditions, as the consistently high external dry-bulb and dew-point temperatures spark a high energy consumption throughout the year, in order to keep zones cool and therefore prevent films from degrading. If indoor conditions are set at the highest acceptable values (10°C and 50%), then the annual energy consumption drops to a bit over 400 kWh/m^2.yr for all four solutions. That means that choosing between an underground and an overground construction does not significantly affect energy use. The difference is however greater in the case of thermal mass. This also triggers a slightly worse performance (compared with ICF and PCM) when indoor conditions are set at their upper limits or average values.

The film stores in Mongolia and Yemen show remarkably lower values, which can be attributed to the lower external dry-bulb and dew-point temperatures (compared with Sri Lanka). In particular, 176 kWh/m^2.yr and 266 kWh/m^2.yr are the highest predicted values in Mongolia and Yemen, respectively. Both values refer to thermal mass (diamonds in Figure 4) and the lowest limits to indoor conditions. In Mongolia, such a value is associated with an underground construction, with the equivalent value in the case of an overground construction being equal to 170 kWh/m^2.yr. In Yemen, the highest value emerges from an overground construction, with an underground construction leading to a similar value (261 kWh/m^2.yr). Hence, similarly to the store in Sri Lanka, choosing between an underground and an overground construction does not greatly affect energy consumption. If indoor conditions are set at their upper limits, the lowest predicted annual energy consumption is 74 kWh/m^2.yr in Mongolia and 149 kWh/m^2.yr in Yemen. Both values emerge from the ICF and PCM solution. All values are also displayed in Table 3 (see 'Appendix').

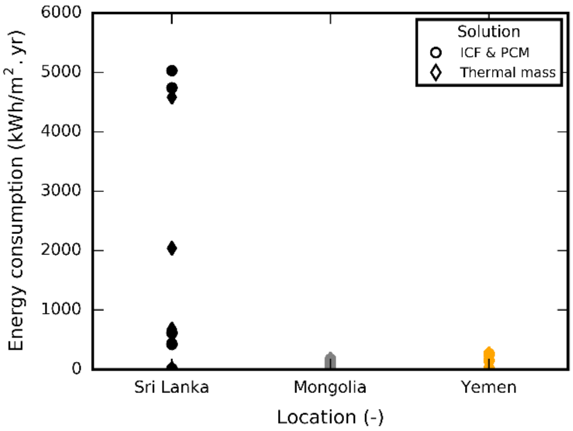

Figure 4: The annual energy consumption of the store across all solutions and scenarios, in all three locations.

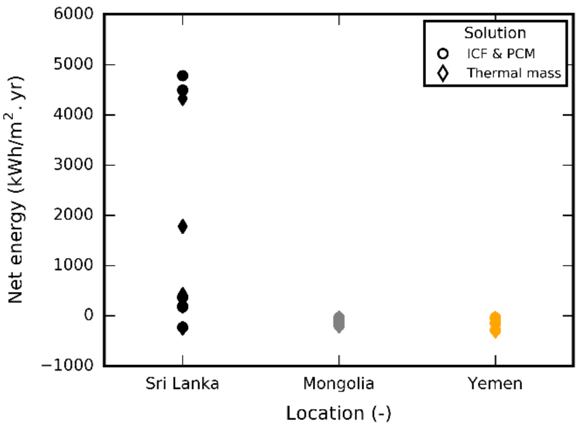

Figure 5: The annual net energy of the store across all solutions and scenarios, in all three locations.

Focusing on the potential of the film store to achieve net zero and reliable energy, Figure 5 illustrates the difference between the annual energy consumption of the store and its energy generation, in all three locations. All solutions and scenarios result in negative values in both Mongolia and Yemen, this signifying the potential of the film store to achieve net zero. In particular, in Mongolia, annual net energy is predicted to vary from -37 kWh/m^2.yr (if indoor conditions are set at their lower limits, hence resulting in the highest cooling load) to -209 kWh/m^2.yr (if there is no service-side solution and thus no cooling). In Yemen, the equivalent values are -36 kWh/m^2.yr and -304 kWh/m^2.yr. Given that the film store in Yemen consumes more energy than the film store in Mongolia, such values indicate that Yemen generates more renewable energy – mainly over winter – which can be attributed to the climatic conditions of the two locations. In contrast, none of the solutions is able to make the film store in Sri Lanka achieve net zero under any of the three scenarios that include cooling, with the annual net energy being equal to 4,782 kWh/m^2.yr if indoor conditions are set at their lower limits. Despite its high renewable energy generation, the film store can thus achieve net zero only under the scenario which does not include cooling, with the annual net energy then falling under -200 kWh/m^2.yr.

Energy consumption vs. usable life

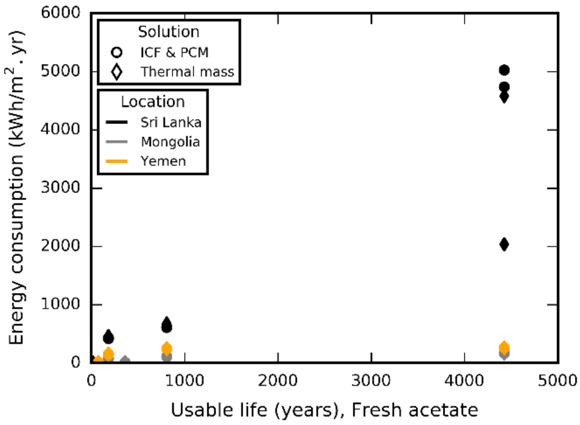

Figure 6: The trade-off between the annual energy consumption of the store and the usable life of its (fresh acetate) films, in all three locations.

In order to assist designers in making informed decisions when designing film stores, Figure 6 illustrates the trade-off between the energy consumption of the film store and the usable life of *fresh acetate* films. Based on the defined indoor conditions, the expected life of fresh acetate films varies from 11 years (if there is no cooling) to 4,426 years (if conditions take their lower values). Not surprisingly, the higher the cooling and dehumidification setpoints, the lower the usable life. If these take their average values, the usable life of films drops to 806 years. If they are set at their upper limits, it further drops to 181 years. Given the lack of constraints on the efficiency of HVAC systems, setpoints are always met. Hence, the usable life of films is the same across all solutions and locations, under all scenarios that include cooling. In the case of no cooling, the lowest usable life is detected in Sri Lanka (11 years), followed by Yemen (73 years) and then Mongolia (359 years). This is due to the fact that, films are susceptible to the climatic conditions of each location, with Mongolia showing the most favourable climatic – and hence indoor – conditions for the preservation of films. In particular, in Mongolia, the absence of a service-side solution results in an annual average internal air temperature of 8°C and a RH level of 38%. The corresponding values in Yemen are 21°C and 30%. In Sri Lanka, these are 27°C and 81%.

Figure 7 displays such a trade-off in the case of *degraded acetate* films. Since their degradation started before being stored at appropriate indoor conditions, they have a much lower life expectancy which varies from 2 years (if there is no cooling) to 978 years (if indoor conditions are set at their lower limits). If conditions take their average values, the life expectancy of films is 158 years. If they are set at their upper limits, life expectancy falls as low as 23 years. In the absence of cooling, Mongolia ensures the highest life expectancy of films (65 years).

Such trade-offs should be taken into consideration when designing film stores, as they reveal the consequences of the decisions about the construction and operation of the

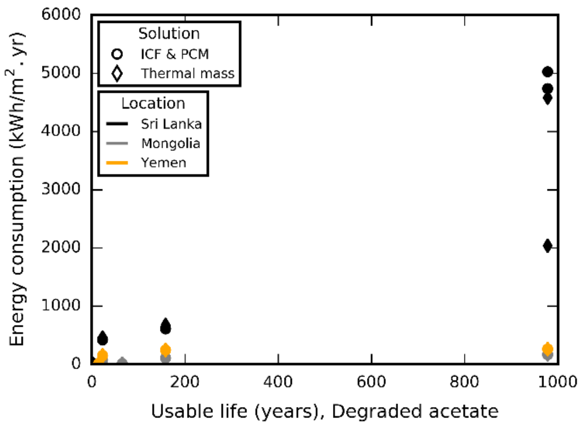

Figure 7: The trade-off between the annual energy consumption of the store and the usable life of its (degraded acetate) films, in all three locations.

stores. Final decisions are however case-sensitive, as they are influenced by stakeholder preferences. As an example, stakeholders may aspire to prioritise the minimisation of CO_2 emissions and running costs, therefore deciding to set indoor conditions at their highest acceptable values (10°C and 50%). This decision would however make films more prone to degrading, with such a trade-off being quantified in this study. Figure 8 can further help stakeholders assess solutions and make informed decisions. The ICF and PCM solution is found to perform better than thermal mass.

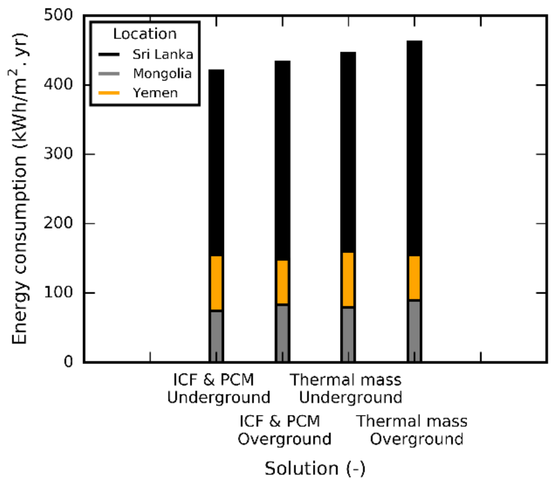

Figure 8: The annual energy consumption of the store when indoor conditions are set at their highest acceptable values, in all three locations.

Conclusion

Despite their high energy consumption (due to the need to store films at low temperatures), archive film stores in the Global South were found able to achieve net zero energy in two out of the three modelled locations (Mongolia and Yemen). Generating renewable energy with photovoltaic panels was essential for securing net zero energy, but also increasing its reliability by eliminating dependence on the existing infrastructure and hence the likelihood of power outages. None of the construction and operation solutions was able to make the film store in Sri Lanka achieve net zero due to the very high external temperature and relative humidity levels throughout the year, which result in a very high energy usage that may even reach 5,000 kWh/m^2.yr when the cooling and dehumidification setpoints are set at their lowest – based on the guidelines of the International Federation of Film Archives – values. Future work could thus explore additional ways of generating energy on-site or off-site, with the latter however increasing dependence on the existing infrastructure and thus reducing reliability. Future work could also explore the interoperability with storage systems such as batteries in order to ensure energy autonomy at all times, and thus the preservation of films and the decarbonisation of both buildings and the grid.

Given the lack of studies on how to extend the lifespan of films while minimising the energy usage of the buildings these are stored at, this paper also visualised the trade-offs between the energy usage of the examined film store and the usable life of both its fresh and degraded acetate films. These provided quantitative feedback on the performance of solutions, which can be harnessed by designers during the building design process. The insulating concrete form and phase change material option performed better than thermal mass in terms of energy consumption, as it helped the film store maintain lower air temperatures. Additional solutions may be explored in the future, as new products and technologies emerge on our way to decarbonisation.

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Appendix

Table 2: Details of the modelled construction solutions: U-values and material layers.

ICF & PCM		**Thermal mass**	
Construction	**Material**	**Construction**	**Material**
Roof (0.15 W/m^{2}K)	White PVC waterproofing Polyurethane hard foam Vapour control layer Cast concrete BioPCM® Q12 panel	Roof (0.15 W/m^{2}K)	White PVC waterproofing Polyurethane hard foam Vapour control layer Cast concrete
External wall (0.12 W/m^{2}K)	White stucco render EPS insulation Cast concrete EPS insulation BioPCM® Q12 panel	External wall (0.15 W/m^{2}K)	White stucco render EPS insulation Cast concrete
Floor (0.13 W/m^{2}K)	Screed Cast concrete Damp proof membrane XPS extruded polystyrene Sand binding Aggregate hardcore	Floor (0.13 W/m^{2}K)	Screed Cast concrete Damp proof membrane XPS extruded polystyrene Sand binding Aggregate hardcore

Table 3: Parameter combinations and the resulted performance values. The annual energy consumption and net energy values were calculated by DesignBuilder (DesignBuilder Software Ltd 2019). The usable life for (fresh and degraded) acetate films were calculated by the Storage Calculator for Acetate (IPI 2020a).

Location	Solution	Indoor conditions		Annual energy consumption ($kWh/m^2.yr$)	Annual net energy ($kWh/m^2.yr$)	Usable life (years)	
		Temperature (℃)	Humidity (%)			Fresh acetate	Degraded acetate
Sri Lanka	ICF & PCM Underground	27.4	81	13.1	-231.9	11	2
		10.0	50	419.5	174.5	181	23
		2.5	35	618.8	373.8	806	158
		-5.0	20	5,026.5	4,781.5	4,426	978
	ICF & PCM Overground	27.4	81	13.1	-231.9	11	2
		10.0	50	432.7	187.7	181	23
		2.5	35	609.6	364.7	806	158
		-5.0	20	4,739.4	4,494.4	4,426	978
	Thermal mass Underground	27.4	81	13.1	-244.6	11	2
		10.0	50	445.9	188.2	181	23
		2.5	35	658.2	400.5	806	158
		-5.0	20	2,038.5	1,780.8	4,426	978
	Thermal mass Overground	27.4	81	13.1	-244.6	11	2
		10.0	50	462.3	204.6	181	23
		2.5	35	679.0	421.4	806	158
		-5.0	20	4,582.8	4,325.1	4,426	978
Mongolia	ICF & PCM Underground	7.5	38	13.1	-196.8	359	65
		10.0	50	74.0	-135.9	181	23
		2.5	35	109.3	-100.6	806	158
		-5.0	20	173.2	-36.7	4,426	978
	ICF & PCM Overground	7.5	38	13.1	-197.7	359	65
		10.0	50	82.8	-128.0	181	23
		2.5	35	113.3	-97.5	806	158
		-5.0	20	168.2	-42.5	4,426	978
	Thermal mass Underground	7.5	38	13.1	-207.7	359	65
		10.0	50	78.96	-141.8	181	23
		2.5	35	117.1	-103.7	806	158
		-5.0	20	175.7	-45.1	4,426	978
	Thermal mass Overground	7.5	38	13.1	-208.7	359	65
		10.0	50	88.7	-133.0	181	23
		2.5	35	115.6	-106.1	806	158
		-5.0	20	169.7	-52.1	4,426	978
Yemen	ICF & PCM Underground	21.4	30	13.0	-288.2	73	14
		10.0	50	154.5	-146.7	181	23
		2.5	35	246.3	-54.9	806	158
		-5.0	20	261.6	-39.6	4,426	978
	ICF & PCM Overground	21.4	30	13.0	-288.0	73	14
		10.0	50	148.6	-152.4	181	23
		2.5	35	249.7	-51.3	806	158
		-5.0	20	264.8	-36.3	4,426	978
	Thermal mass Underground	21.4	30	13.0	-303.8	73	14
		10.0	50	160.4	-156.4	181	23
		2.5	35	246.5	-70.3	806	158
		-5.0	20	261.2	-55.6	4,426	978
	Thermal mass Overground	21.4	30	13.0	-303.7	73	14
		10.0	50	154.8	-161.8	181	23
		2.5	35	251.3	-65.3	806	158
		-5.0	20	265.5	-52.1	4,426	978