Building within environmental boundaries, between need and choice: low-energy, frugal technologies. Learnings from vernacular solutions – a Sudanese case study.

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Abstract

Building design needs to consider that lifetime of its products will likely face environmental and socio-economical changes, and cannot neglect the limits imposed by the geo-biosphere – which is at the same time provider of resources and tank for the waste of our economies. Taking action to face such limits beyond trendy, debatable "green-washing" policies can be either a forward-looking choice or rather something imposed by necessity. The latter is the premise – for instance – of an Italian collaboration between humanitarian NGO *Emergency Onlus* and architecture studio *TAMassociati* in designing hospitals in the African regions of Sahara and Sahel: according to Pantaleo & Strada (2011), many African countries – with their ability to live together with scarcity – represent an example, an opportunity to meditate on some alternative to the mainstream development model, time to time reinventing the thigs. Vernacular building techniques are revisited towards a low-tech innovation that, in a next future, could turn out to be useful also for Western architecture. Some traditional solutions from Sudan and other Countries are here reviewed under a systemic point of view, and presented with the evaluation of their potential advantages in terms of long-term socio-environmental sustainability.

1. Building design within the limits of scarcity

In order to be sustainable and lasting, i.e., able to resist current and future environmental and socio-economical changes, design needs to acknowledge and face such changes. This appears as a particularly suitable good practice when designing buildings, above all buildings that will host services of public interest, since their lifetime is generally projected as far as into the next 50 or 100 years. This implies at least to concede that fewer and fewer resources might be available by then. Although they seem not to have been listened to, the first major warnings about the biophysical limits to growth date back to the Seventies of the twentieth century (Commoner, 1971; Georgescu-Roegen, 1971; Meadows *et al*., 1972; Gorz, 1977). Unfortunately, the limits to the access of resources are not only biophysical, insofar as they involve social consequences such as social inequality, human exploitation, misery and conflicts. Currently, the notion of limit is mainly addressed in talking about the emission of greenhouse gases, and trendy architecture design claims to be taking action by "greening" the balconies or the facades of some yet energy- and resource-demanding steel-and-glass tall buildings. Energy efficiency is more and more addressed, but does not necessarily gives rise to a reduction in energy consumption – in agreement with Jevon's well-known paradox (1865) – being mostly fit in a framework of an increasing general demand. Inside an average Global Northern household, for instance, one might find: heating and air conditioning to have summer temperatures in winter, and viceversa; limitless phone and internet plans to call, share electronic documents, and surf the net *ad libitum* through the most diverse electronic devices, which are replacing books besides regularly replacing themselves due to their planned obsolescence, and so on. In general, the issue of reducing the need for energy and materials altogether is rarely addressed, and a systemic vision is still lacking. This is typical of the so-called "green economy" and "sustainable development", both pursuing economic growth while ignoring scarcity. However, based on the aforementioned changes, in the near future also the Global North might be led to become familiar with the unknown (or unseen) concept of scarcity.

2. African dry regions to imagine alternatives to development

An interesting way to address the (likely) possiblity of such a problematic scenario of scarcity is to measure ourselves with a context where scarcity is the rule, for instance, Saharian and Sahelian regions in Africa. In the following sections, some reflections are presented on a healthcare facility we have been investigating in those areas, namely, the Salam Centre for Cardiac Surgery at the outskirts of Khartoum, Sudan, run and built by Italian humanitarian NGO *Emergency* [1]. Comments are addressed on the forward-looking hybrid solutions employed, based on vernacular building technologies. According to Raul Pantaleo, co-founder of architecture studio *TAMassociati* [2] and designer for *Emergency*, as well as to Gino Strada (2011), co-founder and executive director of the same NGO, Africa can "paradoxically be a laboratory for all the planet, because it can still co-exist – creatively and often lightly – […] with those conditions that the West could need to face in the near future". Building in such a context might represent an opportunity to meditate on an alternative to the mainstream development model, to restart from scratch, where everything is to be reinvented (*ibid*.).

3. The Salam Centre: an introduction to Sudanese case study

The Salam Centre for Cardiac Surgery was built between 2004 and 2007 by *Emergency* NGO, based on a design by architecture studio *TAMassociati* and in collaboration with the Sudanese Ministry of Health. Fig. 1 shows the main facade of the hospital. It provides free healthcare to heart patients coming from over 20 countries[3], being the only hospital of its kind offering free services in Sub-Saharian Africa. The aim of the organisation has been to bring high quality specialistic healthcare – at the same standards as European or United States hospitals – in a deprived area. This choice has often undergone criticism for cost-opportunity reasons, including possible alternative investments to tackle hunger, malnutrition, and primary care instead of highly specialised surgery[4]. By the way, this kind of criticism seems not to take care of the hugely more relevant global and local investements that are *the cause* of hunger and malnutrition worldwide. However, the proposing organisation has always claimed that healthcare – including specialised one – is a universal right, wherever you are from. The Salam Centre is located in Soba, 20 km south of Sudan's capital city Khartoum; it takes up an area of 12,000 squared metres indoor on a lot of nearly 40,000 squared metres on the shores of the Blue Nile river[5]. In the words of our contact person from *Emergency* NGO's humanitarian office, the main driver of the hospital planning and construction phases was just *ethics*. We are actually carrying on a more extended investigation project to find whether this ethics also brings environmental benefits, as well as to track possible positive or crucial consequencies in the society. This will be

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[1] http://www.emergency.it/index.html
[2] http:// http://www.tamassociati.org/
[3] http://salamcentre.emergency.it/En/005/The+Regional+Network.html
[4] http://www.newyorker.com/tech/elements/a-controversial-oasis-of-health-care
[5] http://salamcentre.emergency.it/En/002/Il+Centro+Salam.html

done under a systemic point of view, in particular, by means of the emergy accounting method.

Fig. 1: A detail of the façade of the Salam Centre (photo by architect Raul Pantaleo)

4. Low-energy, frugal technologies

While designing and building its structure, on the left bank of Blue Nile, vernacular solutions and elements were employed, thus merging both the main approaches described by De Filippi and Battistella for architectural projects international cooperation (2014). We will focus on some of the vernacular building techniques, which were revisited towards a low-tech innovation that, in a next future, could turn out to be suitable also for Western architecture.

In the hospital site region, annual average temperature is 45°C. According to Pantaleo (2007), as a cardio-surgical hospital the Salam Centre requires 20°C in its operating theatres, and 24°C in its intensive care rooms, so air conditioning by conventional systems would mean a huge consumption of electric and fossil energy. Despite the oil reserves in the country, *Emergency* NGO decided to provide new, strategically systainable systems based on renewables. This would happen in the same spirit of building a top quality hospital just as it was to be built in any country of the Global North. Therefore, the main energy source available was chosen, the sun (*ibid*.). First of all, passive mitigation techniques were employed to reduce the building energy demand for air conditioning. This was pursued through:

i. the construction of 58-cm external walls with multiple layers of local full bricks, and paneled, insulated air chambers in between (Pantaleo, 2007);
ii. the installation of small double-glass windows protected by sun-screening films[6];
iii. the extensive planting of the land around the hospital with trees and hedges to screen the area from the absorbtion of solar radiation (thus providing environmental mitigation through indirectly resorting to the other local resource available: the Blue Nile's water, used to irrigate these green areas);
iv. the screening of the porticos around the building with panels of loosely twined vegetable fibres (from a local plant similar to a palm), re-functionalising a Sudanese technique used to build beds[6] (as in Figure 2).

[6] http://salamcentre.emergency.it/En/002/004/002/Against+heat.html

Fig. 2: A detail of the porticos of the Salam Centre with the twined vegetal panels on the left and the small double-screen windows on the right (photo by *Emergency* NGO[6])

Such passive mitigation solutions helped reducing the requirements of the hospital, in terms of both financial and environmental costs for its construction, operation, and maintenance. Active solutions to chill the structures consist in a system based on 288 vacuum-sealed solar collectors (covering an area of 900 squared metres). The following information about these solar panels is based on data from Emergency NGO, directly provided to us by its technical division, also summarised and published on the Salam Centre's website[7]. The solar collectors system is able to "cleanly" produce 3,600 kWh, i.e., what would require the burning of over 300 kg of gasoline per hour. Water circulating in copper pipes inside the solar collectors is heated by irradiation, and is then transferred and stored at nearly 90°C inside a 50-cubic-metre reservoir. Hot water produces cooling power by heating up a solution of lithium bromide (LiBr) inside two absorbtion chillers, with the solution reaching the gaseous state thus removing heat and cooling water down to 7°C. Finally, this cold water enters some air treatment units, and cools air to the desired temperatures. Chilled air is then filtered and delivered to the various areas of the building. A spare air conditioning system is present to make up for possible insufficiency of solar energy, composed of two gasoline boilers set up to automatically activate to adjust water temperature inside the reservoir.

Before being cooled by this system, air undergoes a first major filtration from sand and dust (sand storms are frequent in this area at the border between Saharian and Sahelian regions). Filtration is not operated by expensive high-tech filters, but reinterpreting a vernacular technology for ventilation and natural air coolling, typical of other hot and dry areas: Persian wind towers (or *badgir*, see Figure 3), still used in Egypt as well as in some Middle Eastern countries (Dehghani-Sanij *et al*., 2015).

[7] http://salamcentre.emergency.it/En/002/004/003/Solar+panels.html

Fig. 3: Two tall wind towers cool the courtyard of Persian Borujerdi ha House (1857) in Central Iran

Wind towers conduct prevailing winds into the basement of a building, thus cooling the air without using fuels nor advanced technologies. For the Salam Centre, a wind tower was designed with some innovations: a 60-metre-long labirynth-shaped tunnel was built, able to bring the air from an opening at the first floor (visible in Figure 1) down to the basement, where the impact against all the surfaces it encounters makes the dust and the sand fall down, with the air also cooling down due to the slowing down of its speed[8]. The completion of the air's filtering is done through the spraying of the Blue Nile's water (Pantaleo, 2007). As a result, the air is now 9°C cooler than when entering the wind tunnel[8]. This wind tower system as well as the aforementioned passive mitigations for the Salam Centre are schematised in Figure 4.

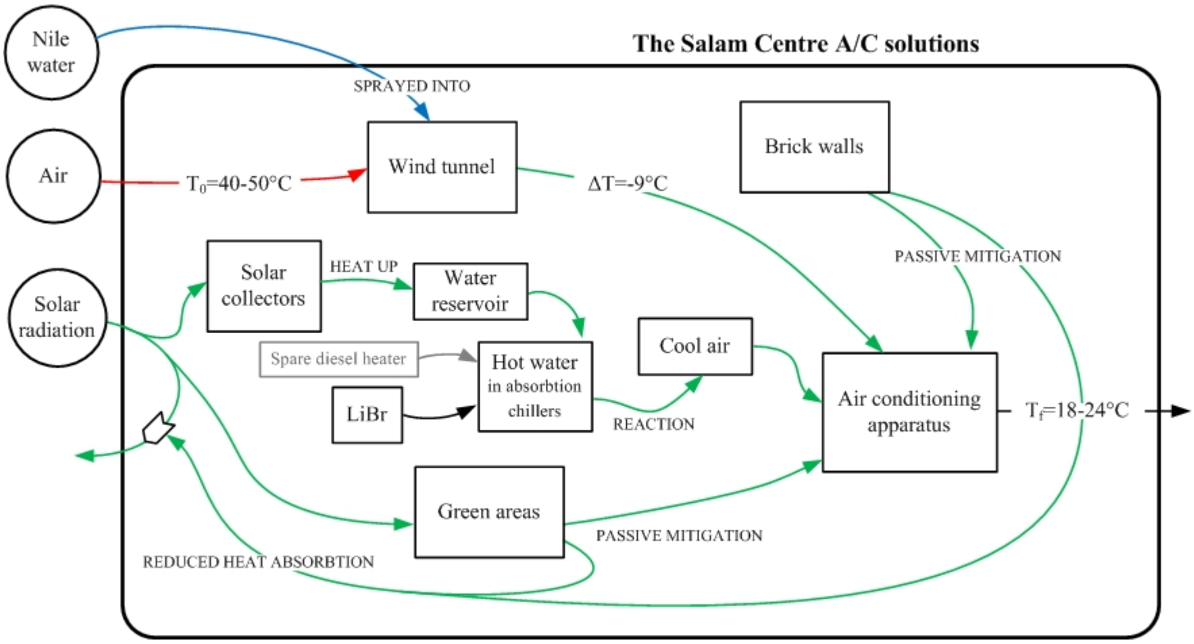

Fig. 4: Scheme describing the Salam Centre solutions for air conditioning through renewables

[8] http://salamcentre.emergency.it/En/002/004/001/Against+dust.html

5. First results of the analysis: eMergy return on investment

Traditional solutions used for the Salam Centre are being reviewed under a systemic point of view, in order to evaluate their potential advantages in terms of long-term socio-environmental sustainability. As illustrated in another study (Cristiano & Gonella, 2017), resource investments in the technologies described in the previous section are yielding high net positive returns in terms of saved nonrenewables: the cumulative energy and material input necessary to realise the wind tower (calculated with an environmental accounting method called eMergy, after "embodied energy" – see Odum, 1996) allows for natural air conditioning, thus saving alternative energy and material inputs (mainly for the production of electricity) for a return ration of over 50:1; according to the same calculation, the solar thermal panel system allows for savings in diesel measurable in a positive energy and material return of three orders of magnitude higher than the required investment (all calculations are made on annual basis). At the same time, the possibility to use clean, abundant, renewable inputs reinforces the hospital system in a medium-long term perspective, when nonrenewables might be scarce or financially expensive, besides preventing the release of greenhouse gases. Through the same eMergy accounting method, a focus will be dedicated to the return on investment of the other low-tech, frugal technologies employed, such as the local bricks or the twined vegetal fibres.

References

Commoner, B. (1971). *The Closing Circle: Nature, Man, and Technology*.

Cristiano, S., & Gonella, F. (2017). Tecnologie costruttive, limiti ecologici e sostenibilità sistemica. L'analisi emergetica per valutare un progetto edilizio tra Sahara e Sahel. *Progetto Re-Cycle*, *4, Il Prato Publishing House, Saonara (PD) (ISSN: 2465-1400,* *http://www.progettorecycle.net/)*.

De Filippi, F., & Battistella, A. (2014). EMERGENCY vs DEVELOPMENT. THE ARCHITECTURAL PROJECT WITHIN DEVELOPMENT COOPERATION. *JUNCO| Journal of UNiversities and international development COoperation*, (1).

Dehghani-Sanij, A. R., Soltani, M., & Raahemifar, K. (2015). A new design of wind tower for passive ventilation in buildings to reduce energy consumption in windy regions. *Renewable and Sustainable Energy Reviews*, *42*, 182-195.

Georgescu-Roegen, N. (1971). *The entropy law and the economic process*. Harvard Un.

Gorz, A., & Bosquet, M. (1977). *Écologie et liberté*. Éditions Galilée.

Jevons, W. S. (1865). *The coal question: An inquiry concerning the progress of the nation, and the probable exhaustion of the coal-mines*. Macmillan.

Meadows, D. H., Meadows, D. L., Randers, J., & Behrens, W. W. (1972). *The limits to growth*. New York.

Odum, H. T. (1996). *Environmental accounting: emergy and environmental decision making*. Wiley.

Pantaleo, R. (2007). *Attenti all'uomo bianco. Emergency in Sudan: diario di cantiere*. Elèuthera, Milano.

Pantaleo, R., & Strada, G. (2011). Centro pediatrico di Emergency in Darfur. *Domus 949, luglio/agosto 2011.*