# Protecting historical buildings is not only a question of respecting their appearance

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## ABSTRACT

**This contribution is strictly related to the one written by Adhikari, Pracchi, Lucchi, (Energy Modelling of Historic Buildings: Applicability, Problems and Compared Results) in which we show the result of the research we are carrying out. This "second" part is more general, because as restorers, we want, to underline some theoretical questions we consider important to building a wider picture of the question.**

**So we want to discuss mainly the concept of energy improvement of historical buildings, that is already present in the European Directives, but has yet to be introduced into Italian legislation. The present delay of its application is due to the difficulties of balancing different needs (conservation, comparison with the performances of elements of efficient contemporary buildings, choice of the parameters for the comparison, etc), the limits of the actual tools for efficiency diagnostics and our current knowledge about historical buildings. A few papers in the literature exist on the topic whilst there are many national and international researches exploring present limits and boundaries. The topic creates interest from many quarters (including the market of new components for historic buildings), nevertheless the balance between conservation needs and enhancement of the performance of the existing buildings is a perspective scarcely followed, due also to the improper analysis tools, methods and parameters commonly used to classify the energy behaviour of historical buildings. This consideration opens the discussion on a different level of the debate, particularly present in Italy, where the issue of substitution of materials and elements of the historical matter crashes into the concept of preserving the authenticity of the historical materials and buildings themselves. The Italian culture of restoration considers it necessary to maintain the historical existing elements, full of unique memories and cultural and social values. The subject of energy efficiency has to be discussed therefore trying to accept the challenge of energy saving combined with the preservation of what we still have now, particularly in those delicate contexts that are not protected by law, such as the historical centres.**



## Keywords

Historical buildings, conservation, energy behaviour, energy simulation tools, windows, cultural and social values, consciousness of users and owners


## 1. Introduction

The sustainability of the conservation of historical buildings has recently included the critical issue of energy efficiency. Nevertheless, only in the last decade have researchers developed an interesting approach to investigating specifically the convenience and compatibility of increasing the energy efficiency of historical buildings [1] due to misled and misinterpreted application of the standards, especially the increasingly compelling requirement to update historical buildings [2]

The European Union standards and their application in the member states did not change the policies of designing new buildings or updating the existing buildings. In fact, since the directive 2002/91/CE the main aim has been "*to promote the energy efficiency of buildings and their components" both new or existing*".

The tools to achieve this goal were the obligation to respect the minimum requirements for energy efficiency and the energy labeling.

The Italian law imposes the validation of the energy requirements of buildings (both the heating and air conditioning) as minimum requirements for the refurbishment of surfaces over 1000 square meters. At the same time, the law imposes the validation of the transmittance of any elements under refurbishment if the surface of intervention (total or localized refurbishment, extraordinary maintenance) is under 1000 square meters.

In general, updating a single building is an intervention belonging to the second category (typically the refurbishment of a building in a historical district).

The energy balance of a large and totally refurbished building has to be global, therefore it is possible to maintain elements and parts with different levels of performance, because they make up for their application. Instead, in the case of small surfaces of intervention, it is possible to upgrade the energy efficiency by increasing the efficiency of the single element under refurbishment (roof, windows, masonry, etc.) up to the acceptable U-values (which are strictly defined by law), without being allowed to evaluate the global improvement of the building's performance by "treating or adding" lacks and excellence. Therefore, the final results can only be the substitution of parts of the existing buildings with high performance elements and materials.

Regarding the energy audit, the fundamental criterion is to take a picture of the energy performance of the building , to know the starting point for a possible improvement. This knowledge is the unavoidable assumption for any further

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intervention, but in the case of historical buildings the result of the calculation is uncertain because of unknown variables (such as the components of the masonry, the thermal properties of the materials used, etc.). Moreover, the software currently available for calculations deals with contemporary buildings, whilst there is no software dedicated to existing buildings, that have different characteristics and operating principles [3]. The results of the present approach lead to poor reasoning, focused on reducing only one variable (money, oil, emission). In fact, up to now research has mainly supported the solution to dismantle a single element (windows, roof, etc.), reducing the project phase of improving the effectiveness of the existing elements and system. The common practice is the substitution of the single sub systems of the structure, and the assumption that the final results of the substitution are more effective than any improvement, without performing any verification.

A reductive approach frequently limits the wider perspective of the necessary calculation of energy efficiency. A wider perspective requires a complete and rigorous economic approach that should include the long term policies, the life cycle evaluation of the buildings parts (from the production to the elimination, throughout the management) together with the opportunities that Cultural Heritage offers.

In Italy, the substitution of existing elements with more effective similar ones depends also on the persisting concept of Protection (and maybe it is the same in other countries): the present retrograde attitude still prefers to preserve the image of the building instead of its materials. Therefore, modifications in the buildings are allowed as long as they are not visible, and precautions are taken to hide new additions and new materials. With the resulting paradox that stone slabs to cover the roofs of ancient buildings in Italy are imported from China.

Nevertheless, rather than trying to camouflage what is modified, perhaps it is worth trying to integrate new and old materials in a contemporary design setting. For example, solar PV tiles can be considered acceptable – giving the benefit of low visual impact – but they still imply a loss of the previous roof cover that, paradoxically, would have been maintained by overlapping other materials with higher thermal efficiency. Furthermore, the new technologies have a quick obsolescence and it would be a pity to sacrifice the previous roof cover in favour of a short term living solution that has to be rapidly substituted. Good common sense and caution are always recommendable when technologies are involved.

What moves the regulators is the anxiety of changing the aspect of historical buildings, and this results in potential exclusion of those buildings from applying new regulations. For example, in the Italian regulations the buildings included in the cultural heritage classification (as per article 136 of the Law number 42 issued on 22 of January 2004) are specifically excluded from the regulations in case of unacceptable alteration of the their aspect. They are eligible for exclusion due to their historical or cultural relevance (D. Lgs. 311/2006 Art. 3 part 3).

The adaptation of existing buildings, specifically in the case of buildings identified as part of the cultural heritage, always poses a key threat: transformations could cause an unexpected decrease of the value of the building.

Legislations tends to solve the conflict between conservation and thermal requirements through the use of deregulation. This should be seen more as an opportunity for a conscious approach and not a way - as often happens - to remove the problems. If the aim is rather to take up the challenge of improving energy efficiency to ensure long-lasting use of historic buildings, this should be achieved without losing their value.

The energy behaviour of historical artefacts could be achieved in a more proper way, and in respect of conservation practices, by applying the same approach currently used in Italy in regard to earthquake regulations: they don't require an old building to achieve the same level of safety (transmittance efficiency in this case) of a new building. Nevertheless, they require the demonstration of an improvement in its seismic worthiness.

As pointed out in the Document of Madrid, dated 2011 [4] the application of standard regulations requires flexible and innovative approaches to ensure appropriate conservation practices.

Therefore, not only is an appropriate legislative framework needed, but also "ad hoc" calculation tools and methods, knowledge of historical building techniques and materials behaviour is required. We should reach a balance between the needs for ancient building protection and their usability and performance.

## 2. A sustainable policy? The case of the replacement of traditional windows

The uncritical application of regulations has already proved to give disastrous results, as in the case of Directive 93/76/EEC Energy Efficiency (SAVE), later repealed, whose purpose was economic incentives for the replacement of windows in buildings already energy efficient. This has resulted in the loss of many traditional windows in Hungary, Finland, Norway, United Kingdom, etc. (Figure 1)

**Figure 1 Old removed windows. (photo by Roger Curtis)**

In Italy, the incentives linked to potential energy savings lack effective regulation and the necessary corrective measures to address different specificities. Coupled with the widespread lack of knowledge among stakeholders, this is producing extensive and uncritical replacement of building elements, especially in the historical centres, where a stringent control - possible for monumental buildings - is difficult to pursue, or is just excluded from the polices.

Moreover, Italy is in a condition similar to that of other countries: replacement of windows and their frames are almost half of the total replaced elements of all the buildings that have obtained incentives for energy efficiency (Figure 2).

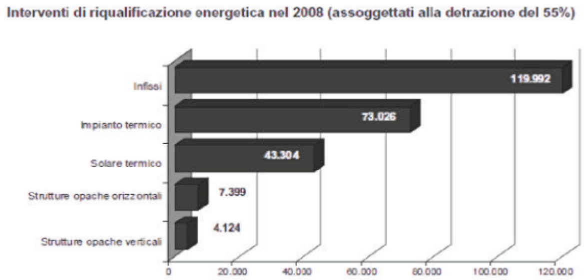


**Figure 2 Retrofit actions on buildings in 2008 (source: CRESME, July 2010).**

A recent report (CRESME, "Analysis of the socio - economic impact of 55% tax deductions for upgrading the energy efficiency of existing buildings", July 2010) says that "the massive usage of window replacements does not involve significant energy savings in the context of the various interventions." (Fig. 3).

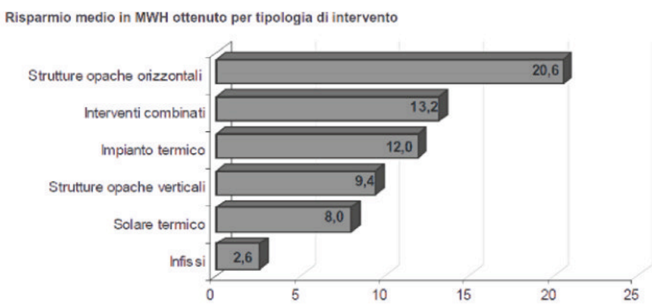


**Figure 3 Average savings in MHV per type of intervention (source CRESME, July 2010).**

The average annual savings achieved, by type of work, in fact shows that replacement of windows has the lowest saving (2.6 MWh). Translated into monetary terms this is about €164 (source ENEA) or between € 80 and € 125 (source CRESME) per year, with payback achieved in 12-15 years.

The Italian Ministry of Economic Development and ENEA are proposing a revision of the incentives mechanism as "it is not appropriate to claim for above the line performance of the transmittances at our latitudes with risk of fake or useless benefits, without paying attention to walls, floors and roofs as well".

The key aspects that must be considered are certainly not the ones that come from the conservators of historic buildings. The first, which obtained an obvious success, is the key driving element for owners, it is the need to improve their own properties. However they consider only low budget interventions and only if properly incentivized. The second is the blatant abuse of the replacement of windows, as regarded in terms of a simple cost/benefit analysis. While addressing the question from the point of view of savings, in a purely economic sense, it should be noted that the historical centres (which constitute the fabric of the Italian territory) - once depleted of their characteristics and transformed into chaotic current buildings - will not no longer benefit in terms of tourism. It brings to mind the scene from an old Woody Allen movie in which the main character descends into hell and meets a sinner, damned for eternity in the lowest group. When asked what crime he is guilty of, the sinner replies, 'I was the inventor of the anodized aluminium window.' (Figure 4).

**Figure 4 A typical case of intervention without attention to materials, details, etc (Photo by P. Giami).**

The other main reason for intervention should be seriously considered: environmental sustainability.

In this regard, research carried out in Norway studied a building heated with electricity. "No emissions of $CO_2$, $SO_2$ etc is taking place as a result of heating the building because energy for heating is based on hydropower. The energy and environmental account, split in consumption of electricity and fossil energy and emissions of $CO_2$, $SO_2$,... are shown in the table. The table covers all the phases from quarrying, production, use and demolition. As seen from the table the energy used in the building during the life time of the windows (90 years) account for almost all the energy consumption in this assessment. The major environmental impact, however, is caused by the production of the windows" [5]. (Table 1).

| | Electricity GJ | Fossil GJ | Total GJ | $CO_2$ g | $SO_2$ g | $NO_x$ g | VOC g |
|---|---|---|---|---|---|---|---|
| **Old windows with single glazed inner frame** | | | | | | | |
| Production and replacement | 1 | 3 | 4 | 87058 | 451 | 1953 | 182 |
| Use | 12524 | | 12525 | | | | |
| Dismantling/Demolition | | 0 | 0 | 114 | 0 | 2 | 0 |
| Total | 12525 | 3 | 12529 | 87172 | 451 | 1955 | 182 |
| **Old windows with double glazed inner frame** | | | | | | | |
| Production and replacement | 2 | 5 | 8 | 130196 | 793 | 3594 | 247 |
| Use | 11993 | | 11993 | | | | |
| Dismantling/Demolition | | 0 | 0 | 194 | 0 | 3 | 1 |
| Total | 11995 | 5 | 12001 | 130390 | 794 | 3597 | 248 |
| **Coupled double glazed windows** | | | | | | | |
| Production and replacement | 12 | 26 | 39 | 713457 | 3978 | 17451 | 1408 |
| Use | 12002 | | 12002 | | | | |
| Dismantling/Demolition | | 0 | 0 | 1057 | 1 | 17 | 3 |
| Total | | 26 | 12041 | 714513 | 3979 | 17468 | 1411 |
| **Energy windows with Argon** | | | | | | | |
| Production and replacement | 13 | 21 | 35 | 766169 | 3450 | 13750 | 1678 |
| Use | 11878 | | 11878 | | | | |
| Dismantling/Demolition | | 0 | 0 | 1032 | 1 | 16 | 3 |
| Total | 11891 | 21 | 11913 | 767201 | 3451 | 13766 | 1681 |

**Table 1 Energy and environmental impact from windows from a period of 90 years (source: Fossdal, 1996).**

It appears clear that something is profoundly jarring within these arguments on environmental sustainability and the current way of addressing this issue.

Moreover, another aspect of our modern deleterious cultural climate emerges from the examination of the case concerning the windows. The lack of maintenance and management practices, that in the past were obvious because it was necessary to preserve something that could not be replaced. The Figure reproduced below, which comes from studies offered by English Heritage [6], shows how simple actions and objects (heavy curtains, close the shutters, double windows, etc.) are highly effective methods for improving the energy behaviour of windows (Figure 5).

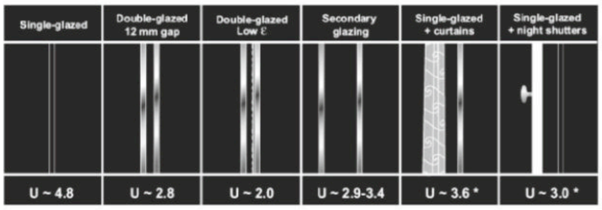


**Figure 5 Comparison of U-values of several type of windows (source: English Heritage, 2004).**

Finally, the most important issue to be discussed for a conservator of existing buildings is the great underestimation of the meaning - in terms of the history of material culture - of the ancient window frames.

"Windows are important historical witnesses. They can tell about a variety of aspects, such as the evolution of design intention and technical possibilities, regional traditions in the use and processing of materials, social structures and habits", hence the assumption that preserving the windows means that "with the transmission of a quantity of information to future generations, the qualities given by the correlation between windows, facades and interiors are preserved and an economical use of resources is ensured"[7].

Re-reading the ancient wisdom of those who manufactured windows and doors is a way to understand the necessary qualities of wood, its different seasoning, the intriguing history of timber manufacturing and glass production, as well as the craftsmanship of their producers. A centuries-old "know-how" that produces, as demonstrated by the aforementioned Norwegian research, windows with a capability of 250-year period service, even when exposed to fierce weather conditions. Also constant care and maintenance are the result of ancient knowledge.

Modern window-frames that characterize modern architecture, wrongly considered impossible to maintain, have different technical problems if compared with the traditional wooden frames, but the approach of finding a compromise between conservation and energy efficiency is valid as well as for historical buildings.

In this regard the refurbishment on the building of the Bauhaus in Dessau [8] allowed an improvement in the overall energy balance with a limited replacement of windows, thanks to the synergy of different strategies, especially related to the displacement of features and the integration of alternative energy sources.

## 3. An overall approach to the building envelope

As shown in the previous paragraph, improving the energy efficiency of one element does not substantially change the energy balance of the historical buildings and its environment. The association of producers of window frames material believes that the risk lies in focusing only on the most immediate aspects of thermal insulation, with the effect of trivializing the solution of such a complex problem and without understanding the path to follow.

As already explained, a reliable assessment of the energy efficiency of historical buildings results only from the application of experimental diagnostics, to determine the real performances of the building, together with the collection of the documentation on the consumption and use, as the energy audit requires. Nevertheless, it is common practice, to prefer the energy audit and the only assessment that the professionals make, because diagnostics is considered an additional cost to reach the same goal, that is the evaluation of energy consumption. The standard does not require the detection of weak elements to improve, therefore the final digit of the consumption is enough to classify the building. As a summary of the previous paragraph, the authors affirm that meeting the standard requirements only mislead the professionals' evaluation from the overall assessment of the buildings.

On the contrary, the approach to historical buildings must consider it in its entirety, including walls and horizontal structures.

### 3.1 Insulation of historical walls

The common practice for insulating the exterior elevation of a contemporary building is the application of external thermal insulation composite systems (ETICS). Any external insulation, normally constructed by fixing sheets of insulating material to the substrate, covering this with a lightweight reinforcement mesh and then rendering on top, is not applicable on the existing finish: it is not a reversible system and its application completely covers and modifies the existing finish, if it is compatible with it. Otherwise the application of ETICS could be effective for only removing the existing coating.

In the case that the finish does not exist any more (or it never has been applied), the application of high thermal performances thermal stucco is possible.

In a contemporary building, thermal leakages are mostly due to the inclusion of non-homogeneous materials, thinner parts of the masonry, and leakages due to the materials or the shape (geometry).

In a historical building, the thermal bridges due to the shape (geometry) are very limited (usually located at the corners), whilst the ancient masonry can include materials with different thermal properties, or different thicknesses, especially if the building has been refurbished or modified in the past, therefore the case of thermal leakage due to non-homogeneous materials can occur. Afterwards, the application of the new thermal stucco could be a solution to prevent damage due to local thermal gradients. The requirements for the new materials are very strict: first of all they should keep the same vapour transpiration that the traditional materials ensure, and second, they should prevent biological germination.

Despite the technical advantages, usually the common criteria for protection refuse to change the exterior elevation appearance, especially if the new stucco has a high thickness (about 5 cm and more) that could conflict with the presence of existing mouldings, and decoration of the facade. At present, the market does not offer many ready solutions that meet both the conservation and the efficiency requirements.

A second path to follow is to intervene on the interior plasters, adding ETICS, or a thin wall butting the interior side of the masonry.

The application of interior plasters with high thermal performance seems to have a wider appreciation, obviously only in the case that the existing plaster has historical or artistic value.

Nonetheless, the application of an interior insulation changes the thermal behaviour of the masonry: the "thermal mass" helps to balance out cyclic changes, e.g. in summer, when massive walls can be cooled during night with colder outdoor air, and allow the room to heat up more slowly during the day. This effect of the massive exterior wall is lost with internal insulation.

In short, interior insulation increases the comfort but also increases the cost to keep it constant. For this reason, this intervention is recommendable only if the use of the building is occasional. A removable device that could be installed during the winter and removed in summer could combine the advantage of insulation layers and thermal inertia of historical masonry, but the market does not offer this solution yet.

Finally, the insulation has to be transpiring, permitting the exchanges of water/vapour from the masonry to the air inside the room. This is a well-known criticality for contemporary buildings, and for ancient ones it is even more critical because of the higher porosity of the materials traditionally employed.

## 3.2 Insulation of horizontal structures

Another important issue is the insulation of the horizontal structures: roof, intermediate floors, ground level.

### *3.2.1 Roofs*

This issue deals with both the technical and management perspectives. The technical issue regards the requirement to ensure ventilation in the attic, with the aim to prevent damage to the roof structure due to high humidity. Ancient structures of the roof are usually timber beams, girders, posts, trusses, etc and the increase of RH over the threshold of 80% causes the growth of mould, fungi, algae etc. and parasites. On the other hand, energy efficiency requirements indicate preventing heat loss due to the lack of insulation of the heated zone. In fact when the heating/cooling fluxes reaches the attic the thermal gradient between the attic and the higher level of the building causes loss of energy across the attic floor, and then across the roof. In buildings that have huge volumes (for example churches) often the need is to heat/cool only the level where the people sit instead of the entire volume. Therefore, in these cases, if the heating system can control the temperature at the lower level (up to 2 m from the floor) it is not necessary to insulate the roof, and even the attic to prevent heat loss at the highest level. At present, heating systems that permit the control of the distribution of heated air mass, use irradiation from warm water pipes set in the floor [9].

Instead, if the use requirement is to heat the entire building volume, up to the attic, the application of insulation on the ceiling at the higher level is mandatory to save energy, if the conservation issue allows the overlap of insulating products; otherwise the application of the insulation should be applied to the attic floor. The insulation of the roof can prevent any air exchange with the exterior: for humid climate the high RH inside the attic could cause damage to timber roof structures. If the insulation is not effective, and the attic is colder during the winter, because of the ventilation, the risk for conservation of the attic floor structures is high, because the thermal gradient between the upper (cold) and lower (warm) side of the horizontal structure could cause water condensation and, consequently, the damage of the materials.

### *3.2.2 Intermediate floors*

The insulation between one and the other of the intermediate levels does not make any sense if there is a centralized heating system, whilst it could be effective if the building is split among many owners/users that use the heating/cooling systems at different times. In this case, the situation could be risky as mentioned for roofs.

### *3.2.3 Ground level floors*

The insulation of the floor at ground level constitutes another relevant matter for the energy efficiency. In fact the thermal insulation of the floor at the lower level could increase the energy saved up to 10-15% of the total amount of the building, according to the models of energy audit software.

Many historical buildings have a high ratio between plan extension and height, most of them have a reduced slenderness (extended plan and few floors). Therefore, the exchange between the floor and the soil could be one of the main source of heating loss.

In the case of poor historic and artistic value of the floor structure and finish, the conservation perspective indicates the substitution with a high performance one. The design of the new structure also takes into account the requirement to host technical crawling space under the floor, and set the technical systems without touching the walls. A new structure, with a good thermal insulation, and water-proof, helps to reduce the rising damp from the soil. And, more importantly, also the damage due to condensation on the colder surface (floor and the bottom of masonry) during the intermediate seasons, when the thermal imbalance of the surfaces are larger..

The new floor may include a heating system (radiant system), that heats a volume 2 m high from the floor, to increase the comfort of the users, without wasting energy. A customized design will take into account also the best solution for different levels, steps, inappropriate finishes that could prevent the access and use of disabled users.

In the case of historical flooring, conservation requires avoiding any change and removal, therefore the need to update the structure to meet the requirements of use and saving energy could be satisfied by adding a technical layer over the floor, fulfilling both the heating function and the insulation. Heating platforms are available on the market, for industrial uses (like sheds, hangars warehouses) and recently also for Cultural Heritage: up to now, the more frequent installations have been in churches and generally in buildings without any heating system. The pros are numerous: the materials could be natural and local (timber); the added layers are removable, and during the good seasons can be housedd in a storage room; maintenance is very easy; energy consumption is low if the use of this heating system is not recurrent, but it could be critical for prolonged usage.

The cons are mainly due to the thickness of the layer, both for accessibility of disabled people and to meet the safety standards (for example, increasing the level of the floor, the height of the window parapet may not be sufficient to protect leaning people out).

And obviously, the use of opaque materials hides the existing finish. Once again, the existing devices could be improved by a specific design oriented to their application in the field of Cultural Heritage.

## 4. Conclusion

It seems that to date a comprehensive theoretical work that analyses in depth the close relationship between sustainability and conservation is still lacking. As well as a vision that takes into account the most recent approaches in conservation, that provides procedural strategies, emphasis in the importance of management, control and preventive maintenance, with the aim of reaching a higher energy efficiency in historical buildings.

Finally, three points emerge from the results of the presented research:

1) The use of more efficient systems and sources of energy, as De Santoli refers: "*Even in the most critical cases ... where it is not possible to operate on the envelope is still possible to work on improving energy efficiency. For example, you may provide energy production systems and high-efficiency technologies for monitoring and managing the most appropriate*" [10].
2) The increase of energy efficiency goes together with the increase of consciousness: the owner, the manager and the user of the historic building firstly have to develop a "smart" way to see and to use the building, improve its potentiality and take into consideration its vulnerability. With the aim of optimizing the resources and their consumption, it will be useful to re-think the use of the building during the day, the week, the season, the year, localize the less and more used zones, the functionality flux, the paths, etc. This scheme could be a starting point to consider where it is really necessary to provide heat or cool air. This research demonstrates that is possible to meet the goals of using the building and conserving its integrity while ensuring adequate comfort to the people remaining in the building.
3) This research also shows that there is a lack of devices that take into consideration the specific requirements for improving the efficiency of historical buildings. For example, only a few current research projects are exploring the possibility of producing insulating system with high perfomance textiles, as well as removable radiant "carpets" and "tapestry", to heat only the surfaces close to people.

It is time to take up the suggestions that come from the past, when sustainability was a matter of life or death, and to invest in our advanced technology to create new systems, elements and behaviours to ensure the best use of our present and future.

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