Marginal Abatement Costs – Focus: Hotel Real Estate

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1. STRANDED ASSETS

The concept of 'stranded assets' is defined in various ways but the commonality is that a stranded asset is an investment which value falls with a lower than expected profitability but that can also be prematurely retired or subject to costly retrofitting and that has become a liability [1, 2, 3]. In the real estate sector, stranding is common due to changing consumer or tenant preferences or because of changes in the regulatory environment (e.g. EU near Zero Energy Building directives) for example. Environmental and natural risks can have an impact on assets being stranded such as properties located at a risk area, for instance at a coastal front where sea water levels endanger the viability of any assets [4]. Climate risk is impacting the real estate investment decision-making and related capital markets. The International Renewable Energy Agency (IRENA) has a clear message to the real estate sector with an estimated USD 10.8T of stranded assets by 2030 in a 'business as usual' scenario [5]. The conclusion of the report is clear: delaying the construction of buildings to the highest standard in terms of energy efficiency increases gravely the risk of stranded assets [6].

2. CARBON PRICING

Carbon pricing has been discussed and implemented in various forms over the past decade whether as emission trading systems (ETS), carbon taxing or some offset mechanism [7]. The main idea behind carbon pricing is to allocate the burden associated to greenhouse gas emissions and consequent climate damage to the emitters. Carbon pricing is thus a price associated with carbon emissions and expressed in value (e.g. €) per tonne of carbon dioxide equivalent (tCO_2e). While there is a growing consensus that some form of carbon pricing is a cornerstone towards decarbonization [8] it is not a 'silver-bullet'. While some form of carbon pricing has been introduced in 46 national and 32 subnational jurisdictions to date [9], decarbonization also requires other instruments and policies such as support towards renewable energy production and zero carbon infrastructure development [10]. Nevertheless, a large section of the private sector has introduced internal carbon prices in their decision-making related to strategic investments and transition or regulatory risk management [11]. However, the hospitality sector as a whole has not yet considered carbon pricing at the rate and breadth required, considering the commitment of more than 70 countries (to date) toward net zero emissions by 2050 [12]. Economists Stiglitz and Stern, in a report published by the World Bank, advocated for a price of up to $100 per tonne of CO_2 by 2030 to drive the promise within the Paris Agreement [13]. In other words, should an owner or investor construct a hotel building today, ignoring a near zero energy approach, the costs of emitting carbon will negatively impact the operators, thus making those inefficient assets very unpopular. Inefficient hotel buildings are at risk of being stranded and shunned by operators, brands and investors unless these buildings can be turned into near or zero energy, low carbon construction.

3. HOTEL ENERGY AND EMISSIONS

Hotels are among the highest energy users per square meter of all commercial buildings [14] with a range of approximately 150 to 500 kWh/m2 depending on the geographical location and type of property [15]. In some markets such as the United Kingdom, the accommodation sector has failed to decrease its overall energy usage compared to most other sectors of the economy [16]. This situation may be explained in parts due to the unprecedented growth in the hotel building stock [17], however opportunities for energy efficiency in hotels are well published [18]. Linked to energy usage are the carbon emissions from fossil fuel usage at the property (e.g. oil/gas for boilers) and purchased electricity from non-renewable sources. The 2020 Cornell Hotel Sustainability Benchmarking study reports average carbon dioxide emissions of 84 kgCO2e per square meter of floor area for US-based hotels but with a significant standard deviation [19]. Carbon footprint in hotels is also often expressed as kgCO2e per occupied room. Results from studies vary quite significantly from 11 to 29 kgCO2e per occupied room [20] and again the variation can be explained by the diversity of geographical location, the final energy mix and type of facilities and amenities provided. The mentioned performance data is based on operational energy, that is the energy required for daily operations from heating, cooling, ventilation and air conditioning (HVAC) to lighting needs. Embodied energy, such as choice of construction materials or refurbishment needs is not taken into consideration. There is disagreement amongst researchers on the overall share of embodied energy over the total energy consumption throughout a building's life cycle. Embodied energy estimates vary greatly with data ranging from 10% to over 65% share of total energy consumption of a building being embodied energy [21]. Considering the ever faster cycles of hotel refurbishment, embodied energy in material and equipment results in a substantial carbon emission share of the overall building life cycle. In a world committed to net zero carbon buildings by 2050 [22, 23, 24] the question is what technologies and environmental initiatives should be implemented in the hotel and in which order, so that the most carbon abatement is achieved at the lowest costs?

4. MARGINAL ABATEMENT COSTS

The marginal abatement cost (MAC) and its curve (MACC) are very beneficial decision-making tools. MAC are the costs (or savings) that decision-makers would incur if they implement a less emission-intensive solution [11]. MAC is a method to compute the costs of a climate intervention by comparing (1) the investment costs and the associated savings discounted over the lifetime of the project with (2) the emissions that the project is expected to abate [25]. Once those costs and emissions abated are placed on a curve, the path that provides the most cost to benefit ratio is visually represented (See Figure 1).

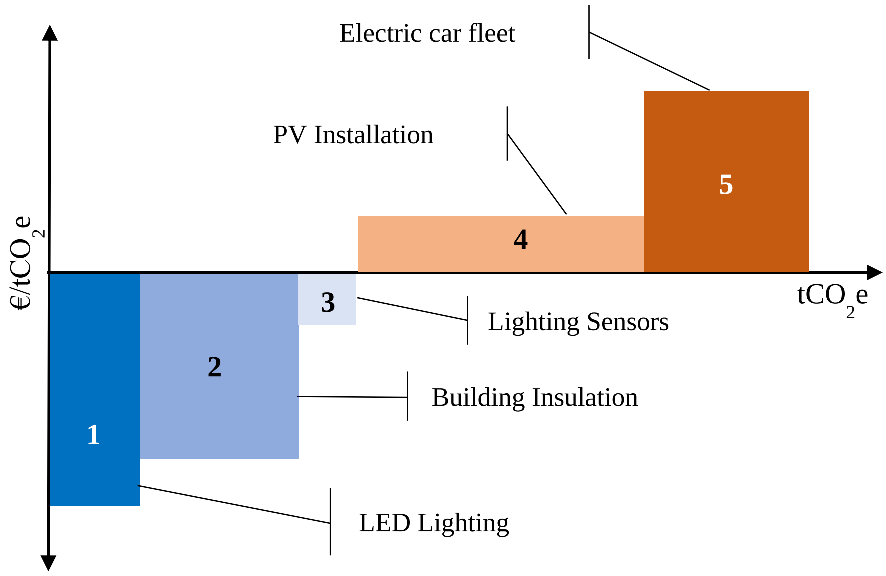

Figure 1. Marginal Abatement Cost Curve
Based on McKinsey & Company (2007). *Costs and Potentials of Greenhouse Gas Abatement in Germany.* On behalf of BDI initiative – Business for Climate

Each box (numbered 1 to 5) in Figure 1 shows projects and associated benefits in terms of financial and greenhouse gas reduction performance. The x-axis represents the volume of abatement in tonnes of CO2e each project can deliver over the evaluation timeframe and y-axis represents the abatement cost in €/t CO2e [26]. This is a visual economic decision making tool to assist business owners and managers in identifying, ranking and prioritising emissions abatement projects. In other words: which environmental initiatives would reduce the most carbon dioxide emissions at the lowest price? When MAC is negative, that is below the x-axis as represented by projects 1, 2 and 3 in Figure 1, the business is saving that amount of money per tonne of CO2e reduced and should be prioritised for implementation [27]. When MAC is positive, that is above the x-axis, then the cost to the company will be that amount per tonne of CO2e reduced. For example, projects 4 and 5 in Figure 1 should be evaluated carefully against other possibilities such as buying offsets for example.

5. CALCULATING MARGINAL ABATEMENT COSTS

MAC is useful for comparing and prioritizing different abatement options. The following formula is applied to calculate the MAC of individual projects:

$$\text{Marginal Abatement Cost } (\text{€}/tCO_2e) = \frac{\text{Net Present Value (€)}}{\text{Total } tCO_2e \text{ abated over the life of the project}} \times -1$$

Figure 2. Marginal Abatement Cost Formula

Following is further information in regards to the calculation of net present value and carbon emissions avoided.

A. NET PRESENT VALUE

In times where the hotel industry experiences or suffers capital constraints, the net present value (NPV) is particularly relevant, relating capital planning and the projected profitability of an investment. NPV is calculated using the following formula:

$$NPV = -C_o + \frac{C_1}{1+r} + \frac{C_2}{(1+r)^2} + \ldots + \frac{C_t}{(1+r)^t}$$

Where:

$-C_o$ = Initial Investment (€)
C = Cash Flow (e.g. yearly savings in €)
r = Discount Rate
t = Time

Figure 3. Net Present Value Formula

In a nutshell, NPV can be summarized as adding all the benefits of your investments over the time period (‘$C_1 + C_2 + \ldots C_t$’ in Figure 3) discounting those to today’s value (‘r’ in Figure 3) and subtracting the original investment (‘$-C_o$’ in Figure 3). The discount rate, as a percentage rate, represents the diminishing value of cash flow over time. Setting the discount rate is often the work of the finance department based on various factors such as the expected return from investors or the cost of borrowed funds [28]. Should an investor expect a 12% return, this can be set as a discount rate for example. Another way to look at it is by using the weighted average cost of capital (WACC) approach. WACC takes in consideration a variety of variables including a company’s market value, cost of capital and debt structure [29]. The resulting rate at which the company finances other projects becomes the discount rate. Independent of the approach chosen, often a greater discount rate is applied to factor in the component of risk and opportunity costs of an investment.

B. CARBON EMISSIONS ABATED

However, the NPV on its own only provides the decision maker with an overview of the highest financial benefit without consideration to the project’s carbon emission reduction. As such, computing the amount of tonnes of carbon emissions saved with each project is the second part of the MAC calculation as shown in Figure 2. In regards to energy usage, a calculation of the estimated change in consumption needs to be undertaken (see 6. PRACTICAL EXAMPLE 1 & 2). Once the amount of energy saved is calculated (e.g. in kilowatt-hours, or in percentage reduction), a hotelier can use free-of-charge methodologies which can help assess the carbon footprint of operations before and after the implementation of a project such as the Hotel Carbon Measurement Initiative (HCMI). HCMI is powered by the Sustainable Hospitality Alliance and used by over 25000 hotels worldwide [16]. Alternatively, it is also possible to determine the emissions abated from the project’s energy savings by multiplying the energy usage by an emissions factor (CO2e/kWh) [see 30].

C. MULTIPLICATION BY -1

As shown in Figure 2, the overall result is multiplied by ‘-1’. Thus, it turns a positive NPV (which is ultimately what business owners may see when all the savings or benefits over the lifetime of a project are greater than the original investment) into a negative abatement cost figure. A negative abatement figure is a saving figure. Should a NPV be negative over the lifetime of a project, multiplying it by ‘-1’ turns it into a positive abatement cost figure and thus a cost to the company, above the x-axis, rather than a saving (see Figure 1).

6. PRACTICAL EXAMPLE 1

The owner of a 100-room hotel is considering two options; (1) retrofitting the hotel rooms with LED lamps or (2) installing a photovoltaic and energy storage system.

LED Retrofits		**PV & Storage System**	
Information: retrofit 45-watt halogen bulbs to 9-watt LED bulbs, 70% occupancy, average of 5Wh/day		Information: installing 10kWp PV system and corresponding energy storage system; subsidies or tax incentives not taken into consideration	
Capital Cost (€)[1]	3,000	Capital Cost (€)[5]	22,500
Operating Savings (€)[2]	5,058	Operating costs/Savings (€)[6]	2,000
NPV (€)[3]	37,181	NPV (€)[7]	-1,311
Emissions abated (tCO_2e)[4]	154.0	Emissions abated (tCO_2e)[8]	81.2
Cost of Abatement (€/tCO_2e)	**-241.37**	**Cost of Abatement (€/tCO_2e)**	**16.15**
Notes/Assumptions 1. 100 rooms, 6 lightbulbs per room; €5 per LED bulb; labour-hour costs for retrofitting not included 2. Based on €0.20 per kWh energy rate 3. Using a discount rate of 7%, over a 12-year timeframe; the expected lifetime of a LED lamp at 5Wh/day usage. 4. Hotel based in Germany; an emission factor of 0.406 $kgCO_2e/kWh$ has been used to represent the greenhouse gas emission intensity from electric generation in Germany from the European Environment Agency, Dec. 2020 (https://www.eea.europa.eu/data-and-maps/daviz/co2-emission-intensity-6). Does not take into consideration a discounting of emissions over the lifetime of the project.		Notes/Assumptions 5. 10kWp system installed on a 80m^2 flat roof facing south-west at an investment costs of €1550 per kWp. Energy storage unit installed at an investment cost of €7000. 6. Based on €0.20 per kWh energy rate; Expected yearly energy production of yearly energy production 10000 kWh 7. Using a discount rate of 7%, over a 20-year timeframe; the expected peak production of the PV system. 8. Hotel based in Germany; an emission factor of 0.406 $kgCO_2e/kWh$ has been used to represent the greenhouse gas emission intensity from electric generation in Germany from the European Environment Agency, Dec. 2020 (https://www.eea.europa.eu/data-and-maps/daviz/co2-emission-intensity-6). Does not take into consideration a discounting of emissions over the lifetime of the project. Does not take into consideration a discounting of emissions over the lifetime of the project.	

Table 1. Summary Cost of Abatement LED versus PV & Storage System

In this practical example, the LED retrofitting project is an attractive proposition as it provides the hotel with a positive NPV and a negative MAC. The investment in a PV & Energy Storage System results in a slightly negative NPV and a positive MAC. This project would probably make sense when compared to carbon offsetting possibilities due to the relatively low MAC of €16.15. Additionally, the owners should consider financial support and incentives associated with the generation of renewable energy which are not taken into account in this example. A reduction of less than €1500 in the upfront investment (so from €22500 to €21000) is enough to turn into the positive NPV and negative MAC.

The values are plotted into a graphical representation (see Figure 4) with the marginal abatement costs in €/tCO_2e on the Y-axis and the total abatement in tCO_2e over the lifetime of the project on the X-axis.

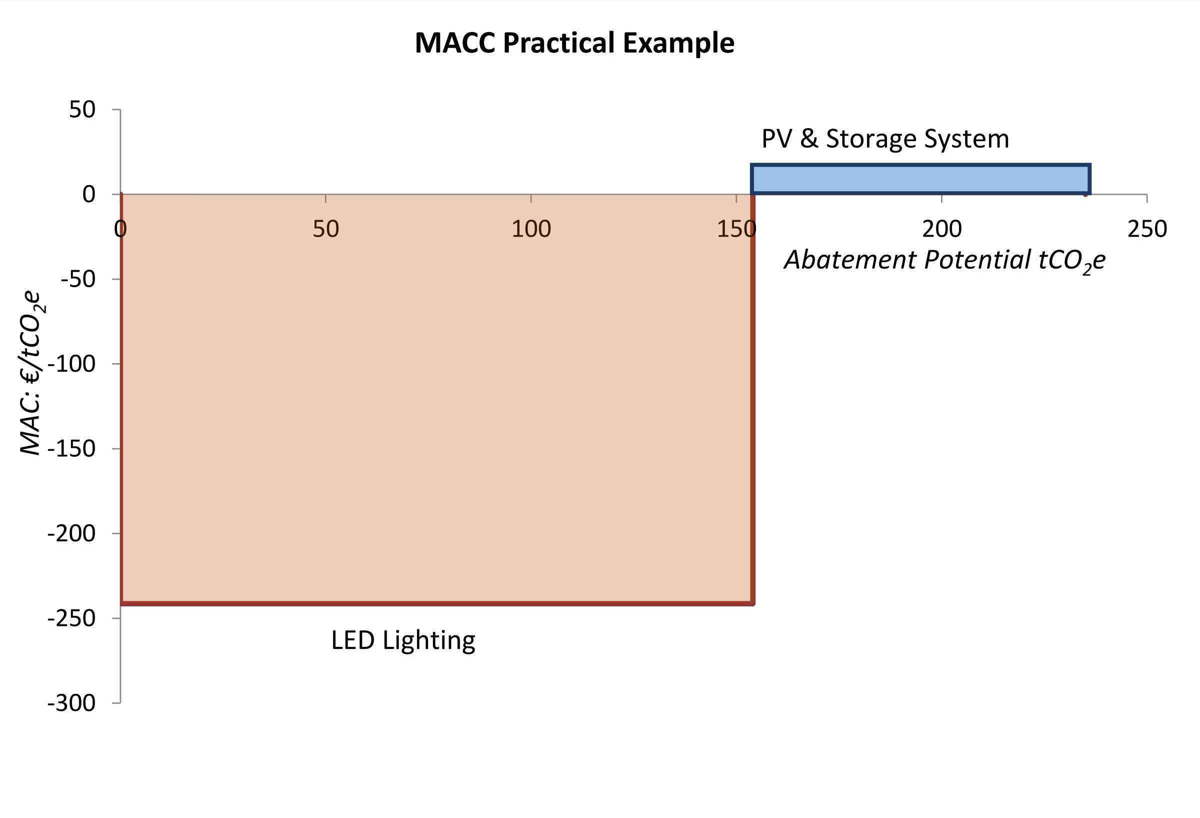

Figure 4. Marginal Abatement Cost Curve Practical Example 1 [(1)]

7. PRACTICAL EXAMPLE 2

The second example illustrates the decision made at the early start of a hotel project. The investor/owner must make the decision between building a standard 3-star hotel following basic legislations in terms of building energy efficiency or invest in a passive house building with high energy efficiency. Here too the MAC can be applied to evaluate the options. The investor wishes to find out whether the investment into a highly energy efficient building makes sense by calculating the NPV, total carbon abated and MAC over the lifetime of 20 years. The timeline of 20 years was chosen as it represents the estimated timeline until the next round of capital investment in energy-related renovations.

Regular Hotel Building Energy Overview		**Passive House Hotel Building**	
Information: The following data is based on a 100-hotel room 3-star hotel with 3500 m² of floor space located in the continental mountainous climate with warm summers and cold winters.		Information: Investment costs for construction of a 100-hotel room, 3-star passive house property is estimated at €8M. This includes 10% additional construction costs due to high energy efficiency components (e.g. thermal insulation, heat recovery unit, window glazing)	
Benchmark energy usage (kWh/m²)[1]	250	Benchmark energy usage (kWh/m²)[3]	120
Yearly energy usage (kWh)[2]	875,000	Yearly energy usage (kWh)[4]	420,000
Energy Savings			
Yearly energy savings (kWh)[5]		455,000	Split into electricity & gas savings
Electricity savings (kWh)[6]		273,000	
Gas savings (kWh)[7]		182,000	
Estimated additional investment due to passive house construction (10% of total construction costs)		Capital Cost (€)	800,000
Results		Operating costs/Savings (€)[8]	73,255
		NPV (€)[9]	40,229
		Emissions abated (tCO_2e)[10]	560.27
		Cost of Abatement (€/tCO_2e)	**-71.80**

Notes/Assumptions

1. Benchmark: Cornell Hospitality Report *Hotel Sustainability Benchmarking Index 2020: Carbon, Energy, and Water*.
2. Hotel floor area multiple by benchmark energy usage; regular hotel
3. Benchmark: *Passive House Institute*: Total specific primary energy demand for certified passive house
4. Hotel floor area multiple by benchmark energy usage; regular hotel
5. Savings between regular hotel and passive house building
6. Based on 70% electricity usage out of yearly energy savings
7. Based on 30% gas usage out of yearly energy savings
8. Based on electricity rate of €0.20 per kWh and natural gas rate of €0.07 per kWh
9. Using a discount rate of 6%, over a 20-year timeframe
10. Hotel based in Germany; an emission factor of 0.205kgCO2e/kWh for gas usage and 0.406 kgCO2e/kWh for electricity generation from the European Environment Agency, Dec. 2020 (https://www.eea.europa.eu/data-and-maps/daviz/co2-emission-intensity-6). Does not take into consideration a discounting of emissions over the lifetime of the project. Total emission abated can be greater depending on the final energy mix (e.g. additional installation of photovoltaic system and sourcing of renewable energy sources)

Table 2. Summary Cost of Abatement Passive House Hotel Building

In this second practical example, building a passive house hotel building is an attractive proposition as it provides the hotel with a positive NPV and a negative MAC.

Again the values are plotted into a graphical representation (see Figure 5) along with the two other projects as presented in chapter 4 for comparison purposes.

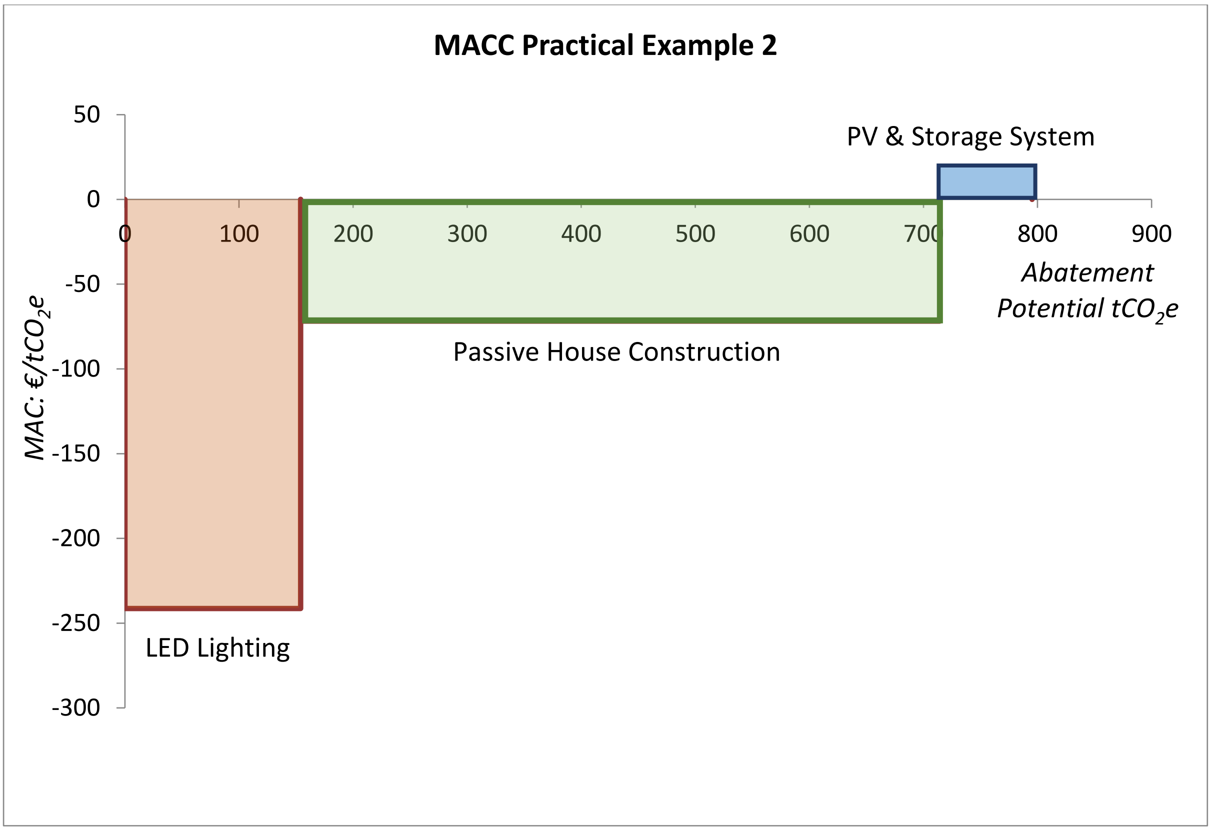

Figure 4. Marginal Abatement Cost Curve Practical Example 2 [(1)]

8. CONCLUSION, RECOMMENDATIONS & LIMITATIONS

As discussed in this paper, implementing the MAC for investment decision-making brings hoteliers, investors, owners and operators (depending on the type and scope and responsibility of investment) multiple benefits. The MACC provides a visual representation to easily identify the initiatives that have negative abatement costs and positive NPV. Applying the MAC methodology to decision making is also a matter of risk assessment and management towards regulatory demands, whether in terms of carbon pricing or energy efficiency of buildings. Finally, using MAC calculations and implementing building efficiency measures is also a matter of mitigating the risk of stranding assets.

The original work by McKinsey & Company is considered an important contribution to the investigation of MACC, and in particular to the development of 14 cost curves for different countries as well as a global cost curve [31]. Although there is no specific MACC developed for the hospitality sector, the knowledge and results derived from building and energy sectors can also benefit the hotel industry [32]. Researchers often corroborate the findings from the practical examples used in this paper. In a nutshell, one can expect negative MAC for the following initiatives: switching to more energy efficient lightning, retrofitting of building envelopes, installing energy-saving electronics and appliances, investing in passive house strategy, and implementing solar water heating and usage of pumps [33].

A few words of caution:

(1) while the MACC provides support in decision-making based on investment costs, savings and abatement potential, it is important to consider other factors in the final decisions. Decisions based only on costs and abatement volume might lead to under-investment in expensive, long-to-implement but high potential options and over-investment in cheap, fast-to-implement but low potential options [34]. In a world dedicated to net zero by 2050, long-term approach is key to many decisions made today.
(2) The practical examples presented in this paper and the resulting MACC do not include taxes, subsidies, and different interest rates. Many countries have set up various support systems to enable a faster transition to net zero in the building sector and this should be taken into consideration when making a final decision.

With an ever expanding supply of new hotels and a large existing building stock which requires extensive retrofitting, filling the existing information gap is essential on the way to a more sustainable hospitality industry. When developed and applied, MACC can provide great insights and an exact plan of action to decarbonize the hospitality industry.

(1) The authors used a standard MsExcel spreadsheet to complete the calculations and graphical representation. Free-of-charge MACC templates are available which may facilitate the computation and graphical representation. Templates data usually require need adjustment to reflect the particularities of a given location (i.e. emission intensity, discount rate).

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