Foundation of Green & Energy Efficient Buildings: Tropical Green and Energy Efficient Performance Certificate

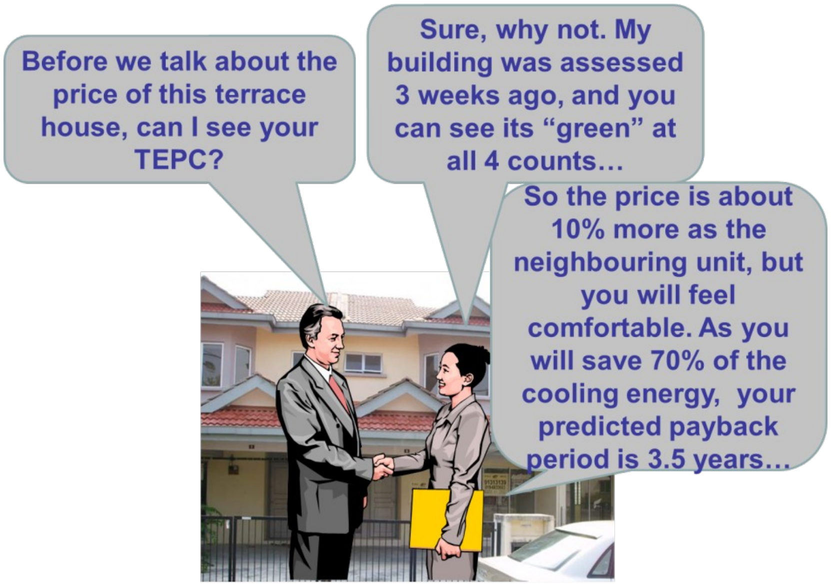
1. Introduction: How Green or Red are You?

Over the past recent years, a high-tech developing country like Malaysia has become sensitive and proactive towards green solutions for the built environment. With the political framework created by the 10th Malaysia Plan, the Green Building Index and the self-commitment of saving 40% of CO_2 emission till 2020[1], Malaysia is on the spearhead of the development in the region to embark on viable environmental survival strategies. The country finds itself at a significant turning point to turn green ideas into practice. The so-called developed countries in the north, most of them with their energy potential being far more restricted, have already devised a wide variety of energy regulations and according renewable technologies that might be adaptable to green buildings. This contribution focuses on the adaptation of the EPC deriving from the European Union and the implications for a tropical country. It comes up with a simple scientific colourful tool kit to measure the CO_2-emission and sketches a case-study related staggered procedure how to save CO_2 according to the thermal comfort needs and affordability of its inhabitants. The proposed and tested toolkit starts with the question for a building how green it is.

Picture: Green Building Mascot[2]

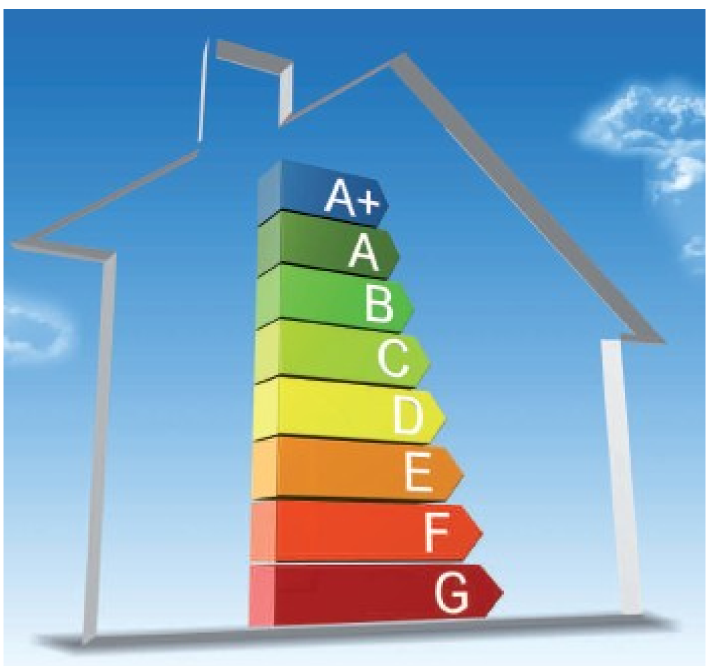
Consider a property developer or a landlord ambitious to sell his or her green and energy efficient building. He has invested in green and enjoys both higher thermal comfort and reduced monthly electricity bills. He can claim he is a greener person, contributing with an effort to save the environment. Will the achievement be rewarded when he strives to sell the building for more as a landlord who did not? At first, let us have a look at the following conversation between a potential house buyer and the landlady about a tropically adopted energy performance certificate (TEPC) for residential housing:

[1] Envisaged by the Prime Minister, Sri Najib Abdul Rahman at the COP Conference Copenhagen 12/2009.
[2] WWW



Picture : Negotiating the Price of a Green & Energy Efficient Building

The often requested idea to implement an Energy Performance Certificate (EPC) for residential buildings is the current practice and furthermore regulation for ANY building in so far 5 countries of the European Union. The **Tropical**-EPC does not mean to copy the origin, but implies a cautious adoption to a warm country where cooling is by far the major environmental issue for the operational costs in the modern built environment. As mentioned in the introduction, and elaborated throughout the chapters on insulation in conjunction with energy efficiency, This tool provides no status of platinum, gold or silver, but distributes school marks from A+ to G aligned with the spectral colours:



Picture 1: Energy Performance Certificate for Buildings[3]

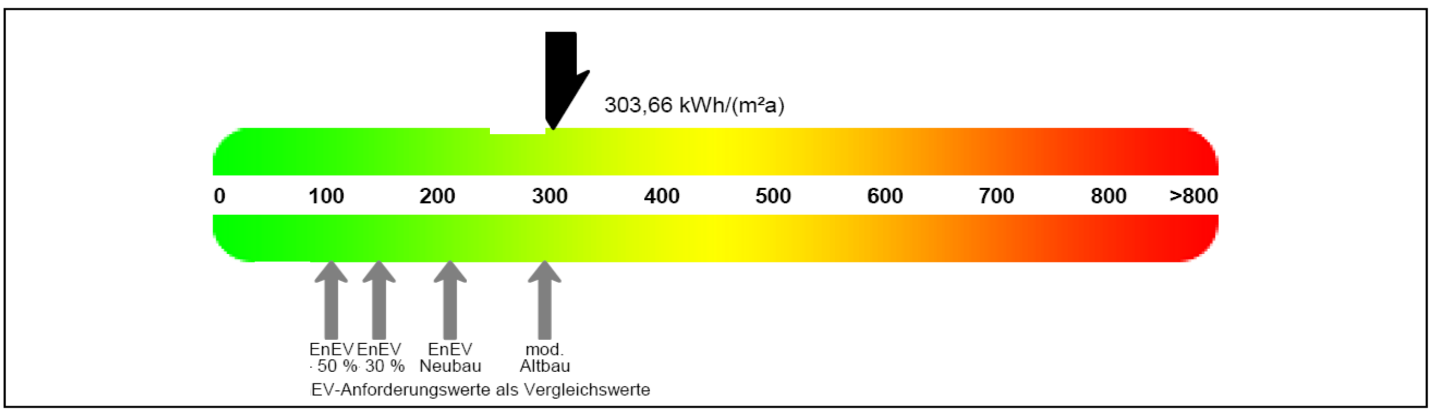
[3] Aluplast Prospectus, 2012.

Following the school marks system, any building's energy performance can be certified between RED and even more than GREEN. A building, which is fully independent or is producing its own renewable energy and even can feed in electricity into the grid, will be granted more than mark "A" or green on one of its following four parts which is energy consumption. The Blue A+ building is self-sustainable like all natural life on our blue planet. In their extremes, A+-buildings are power producers that hence might supply the grid under the Feed-In Tariff (FIT, e.g. Malaysia 2012).

The practical meaning of the TEPC is not a green label solemnly shown to relatives, neighbours and friends how "green" and energy efficient the building is. It is there to assist the occupant or a prospective buyer to gage how to save more energy and hereby save CO_2 in the future. In addition, selling will be facilitated, and the certificate is affordable (following European standards it would be about RM 400), The tool is a substitute and distinct from more sophisticated Green Building Indices (LEEDS – USA, BREAMS – United Kingdom, Greenstar - Australia, DGNB – Germany or GBI – Malaysia). The reason is that the EPC is SOLELY interested to evaluate a) the strength of insulation and subsequently b) the greenness of the electricity consumption in the form of energy efficiency.

Along with three further criteria shown below, the certificate derived by the TEPC will show in how far a building is able to avoid the generation of energy AND, in the BLUE case it will even produce renewable energy for others. It is clearly benchmarked against so-called ideal or real reference buildings. The following European example shows the overall energy` consumption comparing "this building" against other reference buildings with different standards (retrofitted, newly erected, 30% and 50% on the scale of the most recent German Energy Regulation 2012 (EnEV).

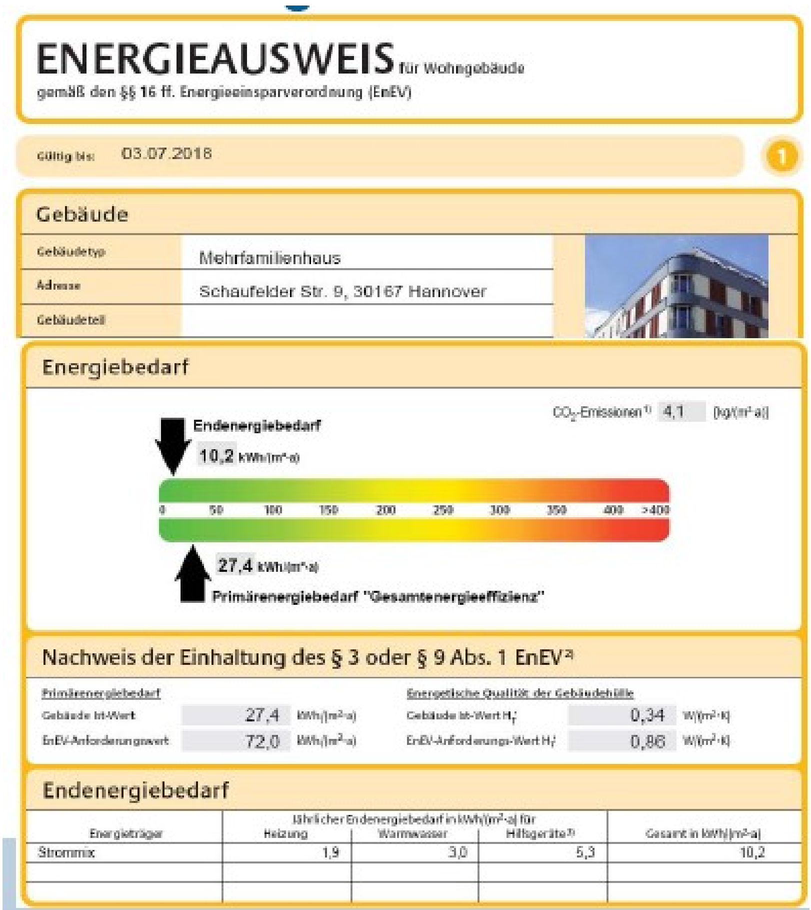
5 4 3 2 1



Picture 2: Scale of Energy Performance Certificate Summary and Example of a Yellow Zone Building

As this "light-yellow" building is an existing building, it falls short of only kWh (m^2a) electricity consumption if it were to comply with the official regulations for ***4. retrofitted building***. That means, only minor renovations have to be undertaken in order to bring it from its 303.66 kWh (m^2a) to the here permitted 295 kWh (m^2a). Proven methods are by replacing single to double glazing with the effect that the primary energy demand per annum will decrease below the targeted value of 295 kWh (m^2a) – if the green building consultant's recommendation (e.g. consumption is monitored by a smart system) is implemented.

The following depiction shows the fully-fledged energy part of the performance certificate of a building in Hannover / Germany of a building which with 10.2 kWh (m^2a) p.a. power consumption and 27.4 kWh (m^2a) primary energy demand is already quite green. Selling this property to a new owner can anticipate the greenness of the building and help to negotiate accordingly towards a much higher market price compared to a common red building2:



ENERGIEAUSWEIS für Wohngebäude
gemäß den §§ 16 ff. Energieeinsparverordnung (EnEV)

Gültig bis: 03.07.2018

Gebäude

Gebäudetyp	Mehrfamilienhaus
Adresse	Schaufelder Str. 9, 30167 Hannover
Gebäudeteil	

Energiebedarf

CO_2-Emissionen[1] 4,1 [kg/(m²·a)]

Endenergiebedarf
10,2 kWh/(m²·a)

0 50 100 150 200 250 300 350 400 >400

27,4 kWh/(m²·a)
Primärenergiebedarf "Gesamtenergieeffizienz"

Nachweis der Einhaltung des § 3 oder § 9 Abs. 1 EnEV[2]

Primärenergiebedarf			Energetische Qualität der Gebäudehülle		
Gebäude Ist-Wert	27,4	kWh/(m²·a)	Gebäude Ist-Wert H_T'	0,34	W/(m²·K)
EnEV-Anforderungswert	72,0	kWh/(m²·a)	EnEV-Anforderungs-Wert H_T'	0,86	W/(m²·K)

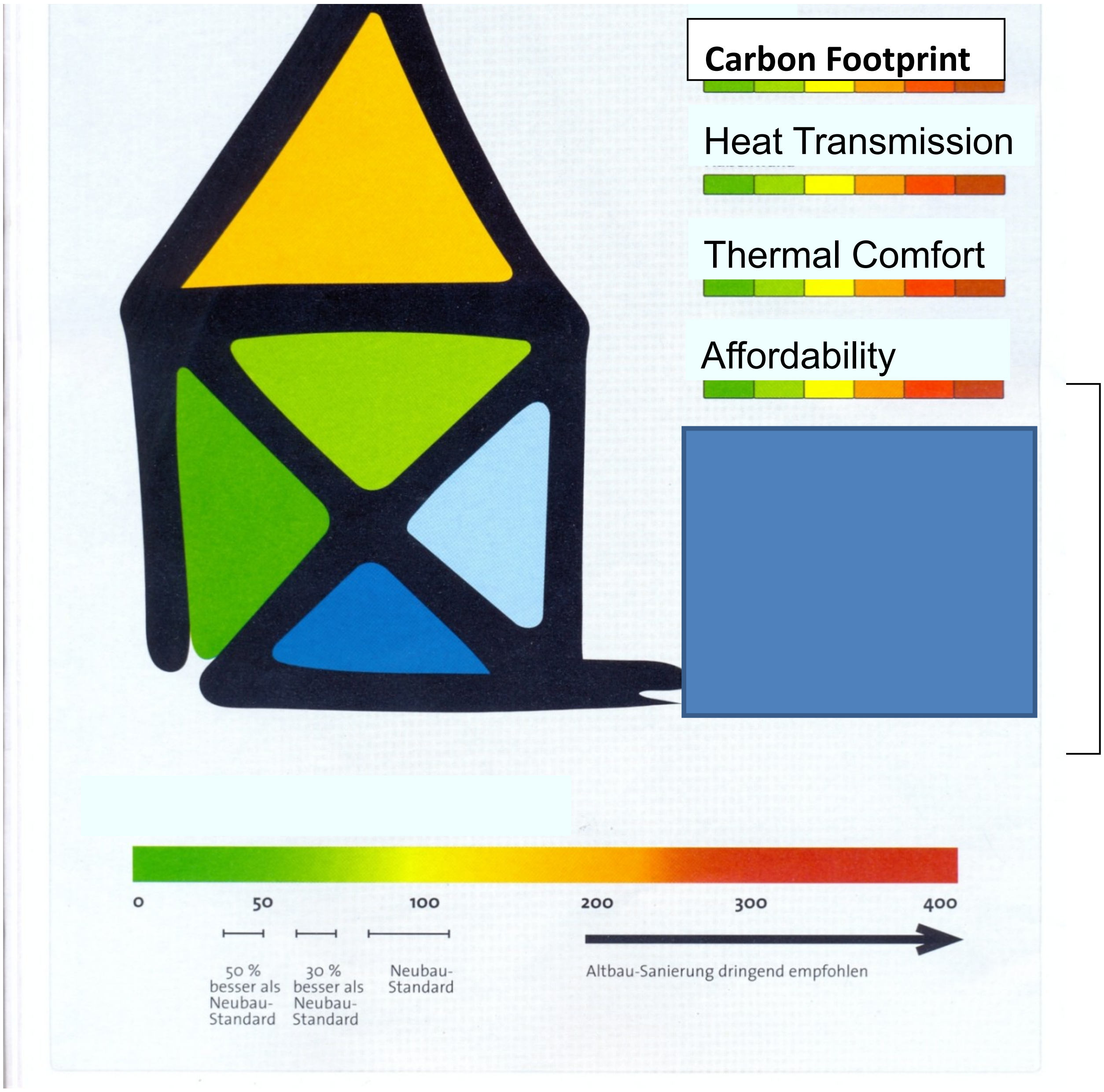
Endenergiebedarf

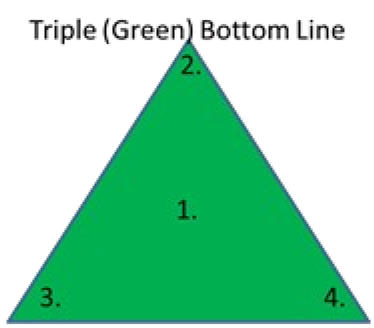
Energieträger	Jährlicher Endenergiebedarf in kWh/(m²·a) für			Gesamt in kWh/(m²·a)
	Heizung	Warmwasser	Hilfsgeräte[3]	
Strommix	1,9	3,0	5,3	10,2

Picture 3: Energy Performance Certificate Residential Building (Germany)

2.S Measuring the Status Quo in a Traditional RED building:

Throughout the following pages, four core dimensions of the Tropically Adopted Energy Performance Certificate (TEPC) will be derived that come out of the Triple Bottom Green Line (chapter I): **CO_2 Emission**, **Thermal Comfort and Cost Saving** as ***output***-factors derive from the so-called magic triangle of green & energy efficient buildings, whereas **Heat Transmission** (optimum insulation, up to air-tightness) is considered an enabler or ***input*** factor. Basically, prior to details elaborated further below, as a summary all of them can be individually measured between green and red:



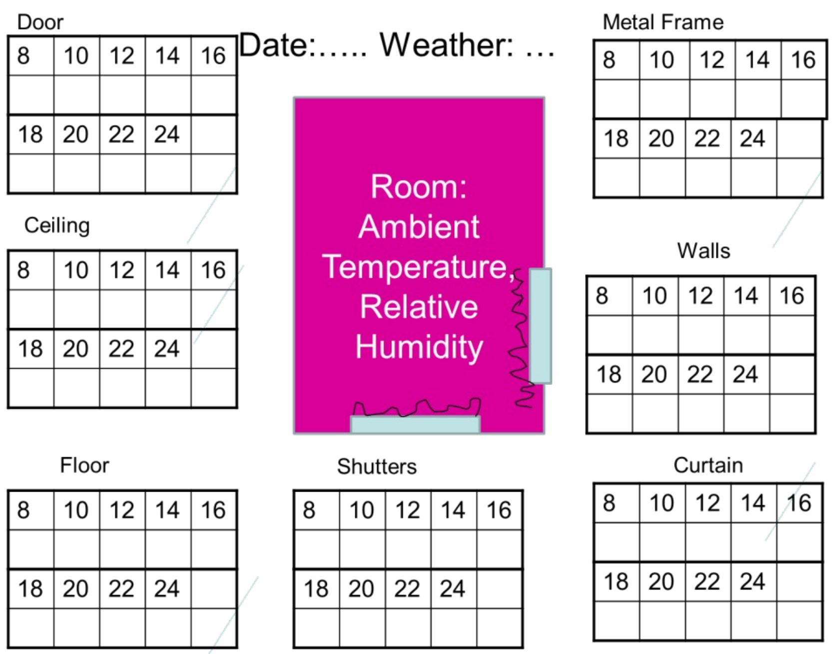


Picture 4: Four Parameters of the Tropically Adopted Energy Performance Certificate and the Magic Triangle (derived from the UN Triple Bottom Line)

In detail, this is the closer look into the four categories paving the way for further discussion:

1. Heat Transmission and Insulation Rate

Within the current measurement, it is common practice to measure heat rejection indicators like R-values, better U-values, A-values, CHI-values and so forth. Within the TEPC, these values as demonstrated in the chapter on “windows” are enablers to reduce the basic temperature. As a concerted action, the approach mobilised here is quite different. Still we are utilising materials in terms of heat reduction, but in the end there is only one relevant factor to determine the greenness or redness of a building’s insulation which is the radiant “surface” temperature of all the following 9 parameters at ***peak*** values during a set of 5 typical sunny cloudy afternoons:



Picture 5: Ambient Temperature of a Room’s 7 Surrounding Elements measured 9 times daily (always compared with Outside Temperature!)

Again, the radiant temperature (respectively the humidity) is considered an input factor which is enabling a building to create an agreeable and healthy ambient temperature inside. It is possible to calculate the ambient temperature by using the single parameters above. The precise way is a mathematical formula that probably still is looking for its creative inventor. The easier way is to trust on statistical values of one’s own research as we did in case of a room in an urban high rise contrasting a rural taman building with the following rule of thumb: The average of the radiant temperature of the room’s 8 surroundings minus 1 = ambient room temperature at a given time. That means if we are able to bring down the radiant average peak day temperature on a sunny / cloudy day from 30 to 29 °C, the ambient temperature will result in 28 °C which is already in range of the tropical thermal comfort zone[4]. If the average radiant temperature is still above 29.6 °C, it would be necessary to cool the respective room further or to decrease the ambient temperature until it is in range and can be maintained. Therefore, the colour scale along with a scale from 0-100 for an overall TEPC-scoreboard looks like the following:

[4] Sabarina et al., 2007. Wagner, 2013

Celsius	COLOUR	Score for overall Scoreboard (continuous)
< 24	DARK BLUE	0-59
24- 26	BLUE	60-79
26-27.7	European GREEN	80-90
27.8-29.6	Tropical GREEN	90-100
29.7-31	ORANGE	79- 50
31-33	RED	50-10
>33	DARK RED	9-0

Picture 6: Blue-Red TEPC-Scale in terms of Surface Temperature of the Building Envelope's 8 Parameters

In contrast to the A+ value of the blue European energy performance certificate, blue in a tropical sense of surface temperature would mean an *over*-delivery of too cold temperatures which are not requested by any occupant. Therefore, the scores (max. 100, min. 0) are low, similar as when the temperature exceeds 29.6°C resulting in the maximum permitted room temperature of 29.6°C. The index also looks into differences in terms of differences between Europeans and tropical people, stating that the green zone in homes might be 1.5 °C higher on average. Another dimension which is not discussed here is the acceptance of higher humidity of tropical occupants. As researches have proven several decades ago, the acceptable temperature is not necessarily only restricted to the fact being a Caucasian who accepts lower, and a tropical human being who favours higher temperatures. The longer a person lives in a tropical country, the more he or she seems to be adoptable with the local standard thermal comfort[5]. The relative humidity is not considered being part of the TEPC, because its effects are highly controllable by our behaviour of taking showers, not eating too late and utilising ventilation.

2. Carbon Footprint

Within this tool, as the only emission CO_2 in relationship with the operation of gadgets is considered. Unlike the Green Building Indices referred to above, the TEPC will NOT include the carbon footprint through the generation and life cycle costs of the building. The reason is that the supply chain of an investment good like windows or walls is not operational, very sophisticated and the measurement might be also be subjectively biased and arbitrary. A building is a long-term investment with the possibility that even the initial carbon footprint will be depreciated through the course of time. In case of walls, doors and roofs, natural biodegradable and replantable local goods might be preferable compared wit those which have to be produced with lots of energy respective carbon footprint. The usage of recyclable material (like in the case of light-weight concrete or wood wool) is a plus, in case we cannot fully rely on natural material like paddy husk or palm oil fibre alone. Furthermore, locally manufactured products and services for an energy efficient green building should be chosen over those from far or from foreign counties.

[5] Ellis, 1952.

If we estimate the life expectancy of our building at 70 years, the carbon footprint of its generation will be factored in to every year of its operation. In addition, by using as many natural materials as possible, even the generation carbon footprint will decrease.
Two measurements can be distinguished: CO_2 / m^3 / year or per occupant. In the following example, we chose "occupant":

CO2/occupant /p.a.	COLOUR	Score for overall Scoreboard
< 100	DARK GREEN	100
100- 129	GREEN	90
130-149	LIGHT GREEN	80
150-169	YELLOW	60
170-190	ORANGE	40
190-209	RED	20
>210	DARK RED	0

Picture 7: Green-Red TEPC-Scale in terms of Carbon Footprint per occupant

The range laid out for the measurement above is based on our own survey asking students of the German-Malaysian Master of Green and Energy Efficient Building-programme to measure their daily and weekly energy consumption. A household with less than 100 kg/ occupant is considered low, whereas >210 is considered quite high. This tool is applicable for houses which are already being in use, not for upcoming houses. However, existing houses can serve as a great benchmark to avoid the generation of CO_2[6].

Description	Built in (Year)	Built-up m2/ Volume m3	Additional Appliances*	Costs/ KWh p.m.	CO2 per capita/ p.m.
1.Flat 5 storey	1986	96.25 m2	*	RM 35.00 160.55kwh	1 160/1= 160
2. 3 storey Terrace House	2008	67m2 Volume: 535.4 m3	*	RM 64 292 kWh	2+1 253/2.5= 121
3. 2 storey Terrace House	1997	98+88 Ground floor = 343 m3 First floor = 660 m3	Water Heater AC	154 RM 700 KWh	3? 607/3= 202
4. Taman Semi-Detached	2009	83 m²	*	RM 38 37.6 kWh	2+1 138/2.5= 101
5. Low-Cost Highrise (level 10, 25 storeys)	?	65 m2	Water Heater	RM 170 775 KWh	6+1 baby 672/6= 139

Table 1 : Case Studies Carbon Footprint per m^3 and per Occupant

[6] Average Scores during 3 times daily with "typical" sunny/cloudy weather conditions, 2 days no rain. Accuracy option for future R&D : 10 afternoons 5-8 pm with different weather conditions

3. Thermal Comfort

We define Thermal Comfort as the *state of mind that expresses satisfaction with the temperature, humidity and velocity of the surrounding environment* (according to the SO 7730 or, likewise, ASHRAE Standard 55). Together with a) environmental sustainability and b) long-term cost saving, c) creating and maintaining thermal comfort for occupants of buildings or other enclosures is the third of the three important objectives of TRIPLE building architecture and engineering. Thermal comfort belongs to the family of basic individual needs. Presuming it is taken for granted or has significantly improved, it enables us in a concerted effort with other physical needs to climb up further the ladder of Maslow's renowned pyramid of needs. Conversely, in its absence, mainstream research holds that any thermal gain or loss above or beyond the following generic borderlines may generate a sensation of discomfort.

A typical Western conception of the state of mind called thermal comfort keeps on believing that the inside temperature for offices should be 21.1° C on average with variations of +- 2.5° C (Thermal Comfort, Fundamentals volume of the ASHRAE Handbook (2005). Of course, in a cold country every °C that has not to be heated can save tremendously energy and budget. In recent years, this figure for thermal comfort has been even proposed to be altered for European offices to 24.5° C, which means an enormous deviation from the internationally renowned ASHRAE-standard (Braatz, 2008). For tropical countries, Busch (1990) carried out a pioneering field study for Thai offices in Bangkok and found that the neutral temperature or effective temperature for the air conditioned buildings and naturally ventilated buildings was 24.5ºC and 28.5ºC, respectively. A similar range of "neutral" conducive temperature was determined for a Malaysian School (Ibrahim Hussein, M Hazrin A Rahman (2009), based on PMV regression is 25.9ºC with a comfort range between 24.4ºC and 27.4ºC. The trendy increase of temperature in offices and public cooled down areas also follows the in-part demise of the common dress code with suits and ties translatable into the 2011 policy by the Malaysian government requesting all state-owned buildings to set-point the temperature not lower than 24°C.
Abdul Rahman (1995) in his ground-breaking study found that the most comfortable indoor temperature in Malaysia (tropical region) for residential areas ranges even from 25.5-28°C narrowing down the general recommendation by World Health Organization (1990) ranging from 18-28°C. Similarly, UTM's researchers Sabarinah Sh.Ahmad, Nor Zaini Ikrom Zakaria, Mohammad Shayouty Mustafa, Mohd Ghadaffi Shirat concluded that a 2.5°C range between 26.1°C and 28.6°C is optimum in tropical countries even for adopted people from Northern countries (2007). Others and our own findings clearly confirm that the optimum residential area temperature for most tropical occupants in their privacy at its highest comfortable end should not exceed 28.6º C. As a conclusion, "the comfort band for the KL area for all building types is between 23.6° and 28.6° C with an optimum medium temperature in Malaysian households of 26.1° C" with the upper space limit (USL) set at 28.6°C". Two reasons can be sorted out. 1) the lower cost when putting the highest set-point in a tropical warm country. 2) the perception by people living in tropical regions is different from those in temperate and cold regions (Wang and Wong, 2007; Singh et al., 2009). The perception is based on lifestyle and habits, and based on economic necessities. All of them contribute to the explanation of the following comparative depiction:

Northern countries	*19.1*	*21.1*	*23.1*	*ASHRAE, 2005 (general)*
"new approach'	*22.5*	*24.5*	*26.5*	*Braatz, 2008 (offices)*
Malaysia (KL)	*23.6*	*26.1*	*28.6*	*e.g. UTM, 2007*

Table 2: Comparison of different thermal comfort definitions

Devising the tropically adopted concept of energy performance for thermal comfort with these higher temperature banding can cause a steep increment in terms of energy saving potentials by 4-7% of less CO_2 and energy cost with each degree centigrade the temperature is increased (Green Efforts Start at 24°C. In: The Star, 12/08/2011, 2). Unfortunately, even if the USL (upper space limit)-temperature is set to its highest end at 28.6°C, in a typical uninsulated concrete building -with the walls, windows, ceiling and roof as permanent heat traps- TTC cannot be achieved during a sunny / cloudy day even in kampong areas (Sanusi, 2010).
We stripped off relative humidity, for simplicity reasons, and for the reason that apart from the A/C it is volatile and hard to control within green cooling. Green makes the humidity more humid, but if we would be able to adjust the rules elaborated in the chapter on green lifestyle, we would not consider the high humidity as a serious issue.

Finally, these are the elements of the TEPC for thermal comfort only for temperatures:

Celsius	**COLOUR**	**Score for overall Scoreboard**
< 22	DARK BLUE	0
22- 24	BLUE	60-79
24-26.7	European GREEN	80-89
26.8-28.6	Tropical GREEN	90-100
28.6-30	YELLOW…ORANGE	70-50
30-32	RED	40-10
>32	DARK RED	9-0

Picture 8: Red-Green TEPC-Scale in Terms of Thermal Comfort

The determination for the greenest of the temperatures above is the one which is able to create thermal comfort along with minimum CO_2 emission at reasonable costs (below). Apart from the environmental issue, it can be concluded that whether blue, dark green or light green is the target of our building is a matter of individual well being. Therefore, European and Tropical Green may have a different weightage. If the temperature is between 26.8 and 28.6, the highest scores can be achieved. The weightage of European green is lower, but might receive higher scores in the Northern atmosphere. Average scores during 3 times daily with sunny/cloudy conditions, 2 days no rain[7].

4. Cost Consideration

[7] Accuracy Option: 10 afternoons 5-8 pm with different weather conditions

The last variable is dedicated to answer the question of the last angle of the magic triangle whether or not and for whom a GEEB is affordable. This is a vital subjective question, because it is widely believed that green buildings are necessarily quite expensive and therefore a NO-GO. Therefore, those who know and would appreciate to become owners, believe they are not able to purchase a new unit or to retrofit an existing one complying with our desired thermal comfort levels above at all time.

a) However, for **new buildings** we can state that following the European principle a passive house (as the most radical version of the green and energy efficient building!) ***may not exceed 110% of the investment costs of a traditional RED building*** with cost saving from the first moment the building is in operation with pay-back periods of less than 1 – 5 years[8]. In terms of the following scale for a residential building, this is still considered LIGHT GREEN:

RM	COLOUR	Score for Overall Scoreboard
Cheaper than standard house	DARK GREEN	100
100 < 110%	LIGHT GREEN	90
111 < 120%	YELLOW	70
121 < 130%	Light ORANGE	50
131 < 140%	Dark ORANGE	30
140 < 150%	RED	15
> 150%	DARK RED	0

Picture 9: Red-Green TEPC-Scale in terms of Affordability (<u>New</u> Buildings)

b) The case of an **existing standard** residential building to be retrofitted clearly again is even more a *subjective* question and answer. Whether it can be greened like in case of the reference buildings (at the beginning of this chapter), an additional investment of less than RM 5,000 with the possibility to break even after maximum 5 years might still be green or red, might mainly depend on three parameters: a) the family's income, b) the cash flow and, first and foremost, c) the readiness to invest into green. Furthermore, one caveat and prerequisite is that the building does a "smart" job, and has to be smarted with additional cost incurred! That means green cooling PLUS building automation can adjust the temperature according to the occupant's wishes at heat peak hours, and react flexibly to the building frame's ability to serve for already much colder temperatures compared to a standard building (elaborated above under pillar 2 - electricity).

The following scorecard presumes that this mid-class household has an annual cash flow of RM 20,000. Therefore, it could easily digest green retrofitting expenditures of RM 10,000 and would still have another 10,000 RM for other cost positions. That would mean that RM 5,000 could easily be absorbed, and up to RM 10,000 are still at "green-light" status with a high consideration for investment.

[8] DENA (2010) Renewables made in Germany.

RM	COLOUR	Score for Overall Scoreboard
< 5,000	Dark GREEN	100
< 10,000	Light GREEN	90
< 15,000	YELLOW	70
< 20,000	Light ORANGE	50
< 25,000	Dark ORANGE	30
< 30,000	RED	15
> 30,000	DARK RED	0

Picture 10: Red-Green TEPC-Scale in terms of Affordability (Buildings for Retrofitting)

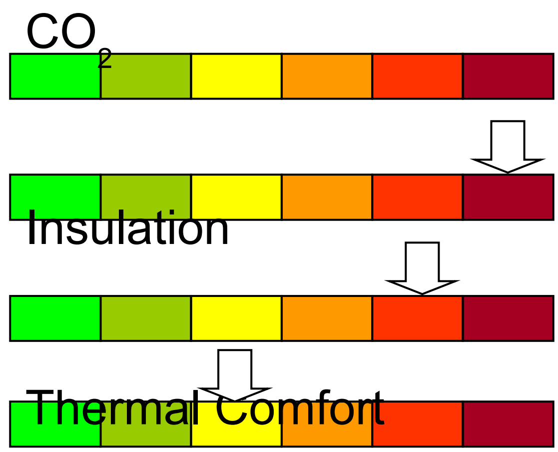
On its RED end, this exemplified scale is left open on purpose, starting with an amount of RM 30,000 which might be quite hard to invest for our mid-class income example above. Of course, the RM 5,000 rule needs to be adopted not only towards the financial capacities of the occupants which are usually the owners (cash flow), but also towards the size of the building

Both scales (new and retrofitting) can now be compared with the payback periods of its investments due to lower operational costs in terms of energy consumption.

In order to illuminate the applicability of the TEPC, prior to generic research ideal type examples for retrofitting have been selected. Out of these, only one case study has been chosen to illuminate the operability of the TEPC for a Malaysian house.

Case Study: Typical 1990s-Retrofitted Kampung House

Size: Estimated 160m^2 *= 480 m*^{3} *cooling load with first floor utilised as bed rooms*
Number of rooms: 5 plus one living lounge and kitchen area
Location: Rural area (not affected by city heat stack effect) with evening temperatures at peak heat days reaching thermal comfort between 9 and 10 p.m.
Occupants: 7 adults, 4 children (age 3-14)
Occupation family head: Carpenter (therefore no labour costs involved for basic retrofitting)



Picture 11: Case Study 1 (Typical 1990s-Retrofitted Kampung House and Applied TEPC)

1: CO_2 = GREEN (only 4 fans, common fluorescent lighting tubes)

2: Building envelopes radiant temperature (measured at peak hour): 34.1 C = DARK RED

3: Thermal comfort (same peak hour): 32.8 C = RED

4: Affordability = YELLOW: In order to bring 1, 2 and 3 into green, the expenses are the following priorities. Monthly cash flow = RM 500 => annual cash flow = RM 6,000.

(1) Insulation:

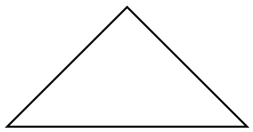
1) insulation of the roof 80m^2 * RM 28	= RM 2,240
2) retrofit existing or add on insulation shutters to all 8 windows. RM 350 * 8	= RM 2,800
3) insulate walls and doors (RM 18/m^2 * 100 = RM 1,800 without labour costs: do –it-yourself social entrepreneurship (occupant's profession: carpenter)) = RM 1,800	
4) fluorescent lighting can be replaced with low-energy tubes	= RM 100
(1) Total Insulation Investment Costs of this Thermally Comfortable Kampung House	= RM 6,940
	===========

(2) Green Cooling (Night-Time Ventilation):

1) 5 exhaust and 5 inhaust fans	= RM 1,500
2) SMART system (option)	= RM 1,500
1) Total Electricity Costs of this Thermally Comfortable Kampung House	= RM 3,000

	===========
GRAND TOTAL	**RM 9,940**
	===========

As the owners profession is carpenter, and he is not fully booked with other commitments, RM 9,940 is the final estimated expenditure to slowly go into green.



3. Outlook

In order to bring down **CO_2** emission, the TEPC can play its part and contribute for masses as it contains a clear business model. Negotiations with internationally operating bodies will show in the near future whether the approach is a viable for developing countries in the tropical and subtropical belt. However, these are potential impasses we have to face

- **Lack of Reliable Research Data**
- **Availability of System Knowledge (playing together as a "Green Orchestra"**
- **Transparency of Professional Benefits (ROI)**
- **Availability of Resources to retrofit**
- **No financial Incentives (market value like EnEV)**
- **Mindset of Owners and Tenants (Short-Term Thinking and other priorities - Demand Preference Structure DPS)**

To overcome these present impasses,

As a summary, four blue/ green to red scales can be determined for the concerted "action" of all four parameters. As a summary, the following table will conclude and set the four parameters as equal with each accounting for 25%.

1. **CO_2 Emission:**
   1. **kWh/Occupant /m**
      or
   2. **KWh/ m^3 /a = CO_2 / m^3 /a** **(25%)**

2. **Transmission loss:**
   Medium Surface Peak Temperature 8 Building Frame Elements
   <1C above TC-line **(25%)**

3. **Thermal Comfort: ambient air temperature <28.7 C (TC-line)**
   (at a later stage relative humidity (50-70%) and velocity (0.2-1m/s) can be incorporated **(25%)**

4. **Costs:**
   1. **retrofitting: 0-50,000**
      or

2. **New building 110%-rule: (25%)**

Table 3: Weightage TEPC

List of References

Abdul Malek Abdul Rahman, Muna Halim Abdul Samad, Azizi Bahaudin, Mohd Rodzi Ismail (2009), *Towards a Low-Energy Building Design for Tropical Malaysia.* Penang: USM Press

ASHRAE (2008), Thermal *Comfort*. Fundamentals volume of the ASHRAE Handbook, Atlanta, GA.

Byrd, Hugh, *Energy and Ecology. A View of Malaysia Beyond 2020.* USM Publication. Penang 2008.

DENA (2009), *Renewable Energies made in Germany.* Berlin.

Ellis, F.P., *Thermal Comfort in Warm, Humid Atmosphere: Observations in a Warships in the Tropics'*, The Journal of Hygiene, 1952.

German Federal Ministry of the Economy, *Energieeinsparung (Energy Saving).* In: http://www.bmwi.de/BMWi/Navigation/Energie/Energieeffizienz-und-Energieeinsparung/energieeinsparung.html.

Godish, T.(2001) Indoor Environmental Quality. Boca Raton: CRC Press.

Ibrahim Hussein, M Hazrin A Rahman (2009), Field Study on Thermal Comfort in Malaysia. In: European Journal of Scientific Research ISSN 1450-216X Vol.37 No.1 (2009), pp.134-152.

Sabarinah Sh.Ahmad, Nor Zaini Ikrom Zakaria, Mohammad Shayouty Mustafa, Mohd Ghadaffi Shirat (2007). *Achieving Thermal Comfort in Malaysian Building: Bioclimatic Housing. Universiti Teknologi MARA Skudai, Malaysia.*

Tuschinski, Melita, EEWärmeG + EnEV Kurz-Info und Praxis-Dialog: *Erneuerbare-Energien-Wärmegesetz und Energieeinspar-Verordnung anwenden. EEWärmeG + EnEV. Briefing and Practical Dialogue:Renewable-Energy-Law and App lication of Energy Saving Regulation*). Berlin 2010.

Volland, Karlheinz, Volland, Johannes, Dirschedl, Dieter and Fichter, Martin.*Wärmeschutz und Energiebedarf nach EnEV 2009: Schritt für Schritt zum Energieausweis für Wohngebäude im Neubau und Bestand. (Warmth Protection and Energy Demand according to EnEV 2009: Step-for-Step to Energy Performance Check for Residential Areas)* .Müller. Verlagsgesellschaft. Nürnberg 2009.

Wagner, Karl (2013), *Tropical Thermal Comfort and Adapted Tropical Green Residential Housing.* In: Conference for Affordable Quality Housing. Putra Jaya 13/03/2013 (V).

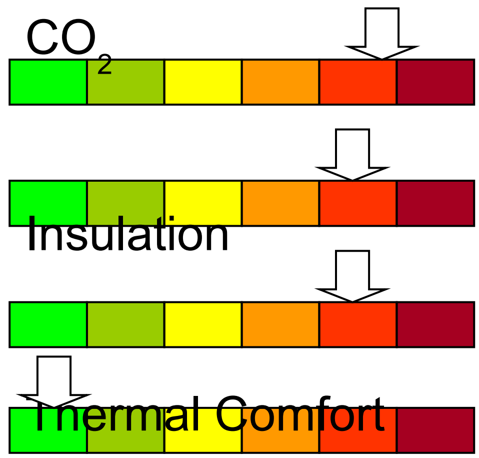
Wang, L. and Wong, N.H. (2007). *Applying Natural VVentilation for Thermal Comfort in Residential Buildings in Singapore.* Architect. Sci. Rev.,50: 224-233.

Weglage, Andreas, Gramlich, Thomas, v. Pauls Bernd,v. Pauls Stefan *Energieausweis - Das große Kompendium: Grundlagen - Erstellung - Haftung (Energy Performance Certificate - Basics - Procedure – Legal Issues.* Vieweg+Teubner, Stuttgart. 2009

Zalina Shari, *Building Performance Assessment Systems: The Emergence and the Variety*. In: UPM Housing Research Centre, Housing News Issue 12, Jan – Jun 2012:7.

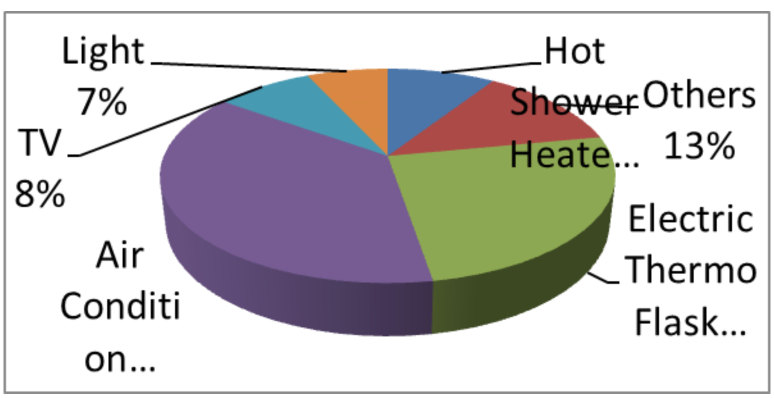
Example 2: Typical Terrace House Center (KL) Area (1997)

Size: Ground floor = 98 m^2, First floor = 88 m^2 (cooling load 558 m^3), Car park area = 56 m^2
Location: Suburban area (not affected by city heat stack effect) with evening temperatures at peak heat days reaching tropical thermal comfort level at sunny / cloudy conditions between 8 and 12 p.m.
Occupants: 5 Adults



Picture 12: Case Study 2 (Typical Terrace House Center (KL) Area (1997) and Applied TEPC)

The average electricity consumption p.m. is about 700 kWh = RM 154 per months. The following appliances are in use (one common air condition used 8 hours usually during nighttime):



Picture 13: Energy Consumption of Terrace House KL

The TEPC will yield the following results:

1: CO_2 = RED 2: install cross-ventilation during night time
2: Building envelopes radiant temperature (measured at peak hour): 32 C = RED

3: Thermal comfort
same peak hour: 31 C = RED
23 C = BLUE (night time average temperature sleeping room at the same day with air condition unit)
29 C = ORANGE (dto, but instead of air condition stand fan)

4: Affordability = GREEN: In order to bring 2 and 3 into green, the expenses are the following priorities:

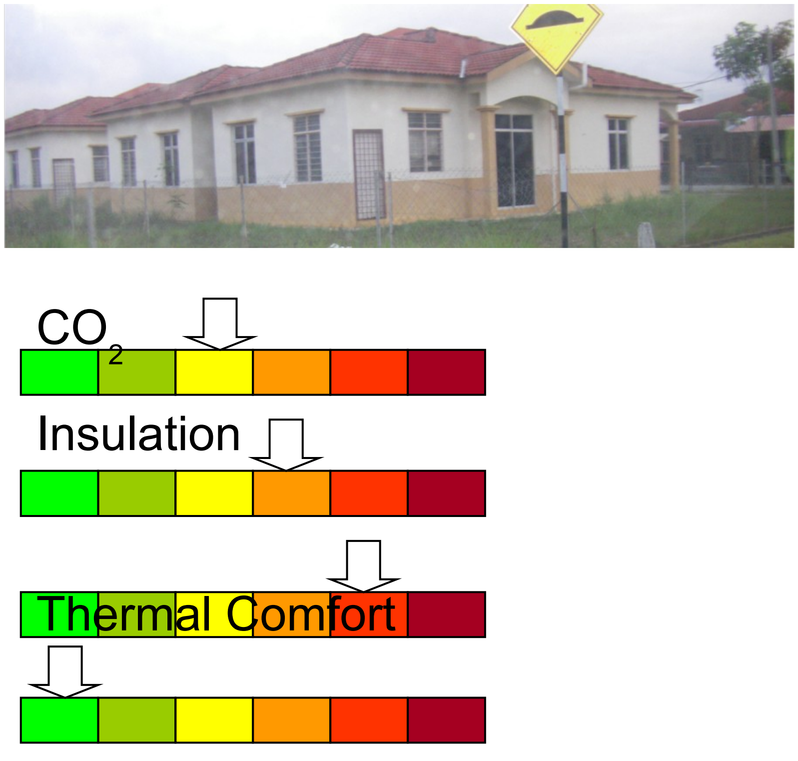
1) insulation of the roof (RM 10,000)
2) add on insulation shutters to all 8 windows (RM 350 * 8 = RM 2,800)
3) insulate walls and doors (RM 20,000)
4) air condition unit in 3 sleeping rooms to be fitted with interrupter, lighting can be replaced with low-energy tubes) (RM 1,000)

As the cash flow of this family with 3 adults working equals RM 3,000 per month, this expenditure is affordable.

As a conclusion, even though this building is in RED areas in terms of CO_2 emission, insulation and thermal comfort without air condition, it has the highest potential among the three case studies. Moreover, as the family income is considerably higher than in case of case study 2 and 3, the chances to green this building are high, if the occupant who is the landlord has created awareness, and finds GEEB consultants to guide him or her.

Example 3: Typical Semi-Detached Taman House (2006)

Floor Plan: 83.6 m² and cooling load 271 m^3.
Description: This is a semi-detached standardised house located near Penang. It was chosen because like such as for many of them, they are standardised and natural or aided shading is not provided at all. Sun-lit locations can be typically found in many areas where the existing trees and plants were indistinctively chopped during construction, and landscaping is restricted to sawing grass on unfertile soil. When the sun rises in the early morning, it will hit the East window and remain until 11.30 a.m. -12 p.m. Following the logics of the sun's course, the windows at the south front of this semi-detached building will be hit by the sun 11 a.m. onwards, shining in at different angles until the sun goes down at an angle of 15 degree before it will vanish to the West front. As a result, the window of the West front will be hit 1.30 onwards until 45-60 minutes before the sunset.



Picture 14: Typical Park Area House and Applied TEPC

1: CO_2 = YELLOW (thermoflask to be replaced by energy saving thermoskanne , lighting can be replaced with low-energy tubes)
2: Building envelopes radiant temperature (measured at peak hour, but persists at high level throughout the entire night): 32 C = ORANGE
3: Thermal comfort (same peak hour): 32.5 C = RED
4: Affordability = GREEN: In order to bring 2 and 3 into green, the expenses are the following priorities:

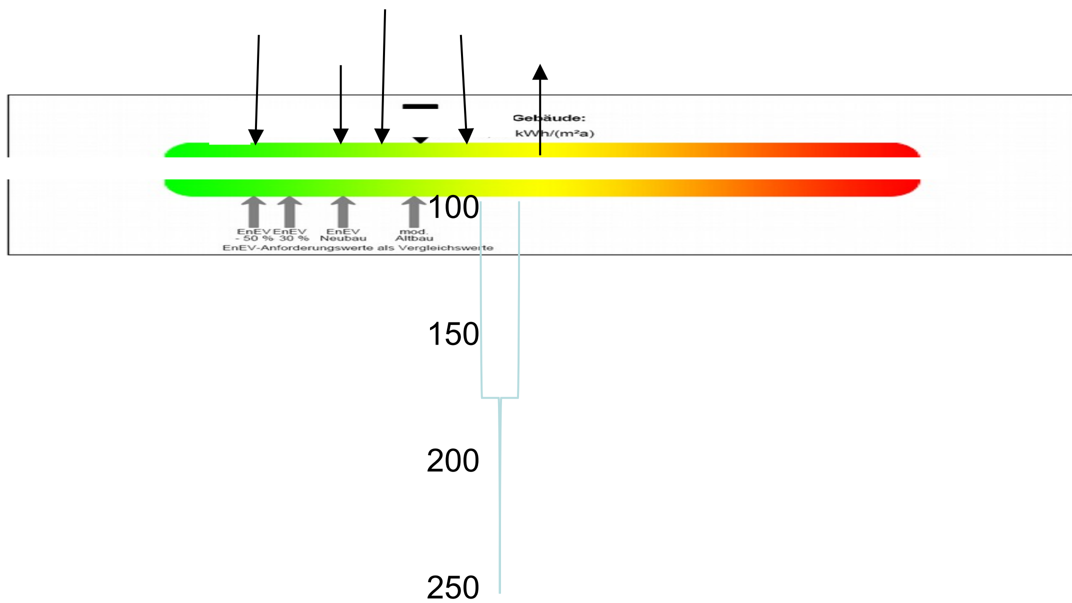
1) insulation of the ceiling (RM …) Heat Shield
2) provide active night-time cross ventilation
3) add on insulation shutters to all windows (RM
4) insulate walls and doors

Using thermoventilation to bring down the electricity costs can be considered as if the buildings are getting German measles:

Picture:

This might also account for the comparison between a tropical RED and an ideal type GEE-building as exemplified in the following table:

Picture 14:


Gebäude:
kWh/(m²a)
100
EnEV
- 50 %
EnEV
30 %
EnEV
Neubau
mod.
Altbau
EnEV-Anforderungswerte als Vergleichswerte
150
200
250