SIX SENSES
RESORTS & SPAS

The Carbon Advisory Service Ltd.

Soneva Fushi Maldives
Work-in-progress Interim update

15th September, 2009

Headlines

The Carbon Advisory Service Ltd.

- Only about half of electricity use has currently been accounted for – it is likely that better energy-efficiency is the single most significant measure.

- A combination of waste heat-driven chillers, anaerobic digesters and photovoltaics are the recommended backbone of the energy supply strategy.

- Biocharing branches and naturally occurring "woody" biomass is recommended as a way of sequestrating carbon and creating a useful by-product

- Also being considered is an alternative to the Reverse Osmosis (RO) machine.

- It is likely that the deep seawater pipe should be re-used, probably at a reduced length, as a means of rejecting heat from the chillers.

- Currently electric water heating is used for the restaurants. Electrical generators produce twice as much heat as they do electricity. However most of the heat is being thrown away and valuable electricity used to heat the water.

- Restaurants should heat hot water using; either heat reclaimed from the electrical generators, solar-thermal collectors or heat from the biochar. This one service is using about as much electricity as the whole PV installation generates.

- Bamboo is recommended only where this can be done without deforestation, perhaps off-island.

Contents

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Summary

The following strategy has currently been explored:

- Replace the existing electrical generators, which are too large, with smaller diesel-fired Combined Heat and Power (CHP) units - *same amount of electricity out, plus twice as much energy as heat, for the same amount of fuel in.*
- Provide a site-wide cooling network with central absorption chillers powered from the waste heat off the new CHP units.
- Biochar all branches and other “woody” biomass.
- Use organic digesters to gasify food waste and “leafy” biomass. The gas is then used to continuously power a 20 kW electrical generator.
- Install 70 kW of PV. Any new PV to make use of suitable roofs rather than clearing forest
- All hot water, including catering hot water, to be supplied by local solar-thermal panels, the CHP plant or the biochar units and not electrically heated as currently.

The total saving resulting from these measures is estimated at 1,175 tonnes CO_2, or 34% of total emissions from the diesel-electrical generators. This is obviously far short of the target of being carbon-neutral, however there are a number of areas still in progress that should significantly improve this situation, they are:

- Complete the audit of the thermal modelling. If the figure should be higher than the current preliminary results, then the absorption cooling will provide a larger saving than currently shown.
- Notwithstanding the modelling audit, the cooling, lighting, Reverse Osmosis (RO) plant and catering hot water appear to explain only around half the total electricity consumption – perhaps less. The other 50% or so needs to be identified and mitigated; this could reduce emissions by a further 30% or so.
- Opportunities will be explored to provide solar desalination to save 8.5% of current electricity use.

A key development that occurred during this stage was the realisation that the planned bamboo farm would require deforestation. This would reduce the carbon benefit and could have a detrimental effect on the native biodiversity. For this reason, the 10 acre bamboo plantation is not recommended: biocharing natural forest wastage has been recommended. Similarly, it is recommended that any additional PV modules are located on roofs to avoid clearing trees.

Introduction

This interim report is offered as work-in-progress so that CAS can share its progress with the team, seek direction and raise awareness of matters of interest.

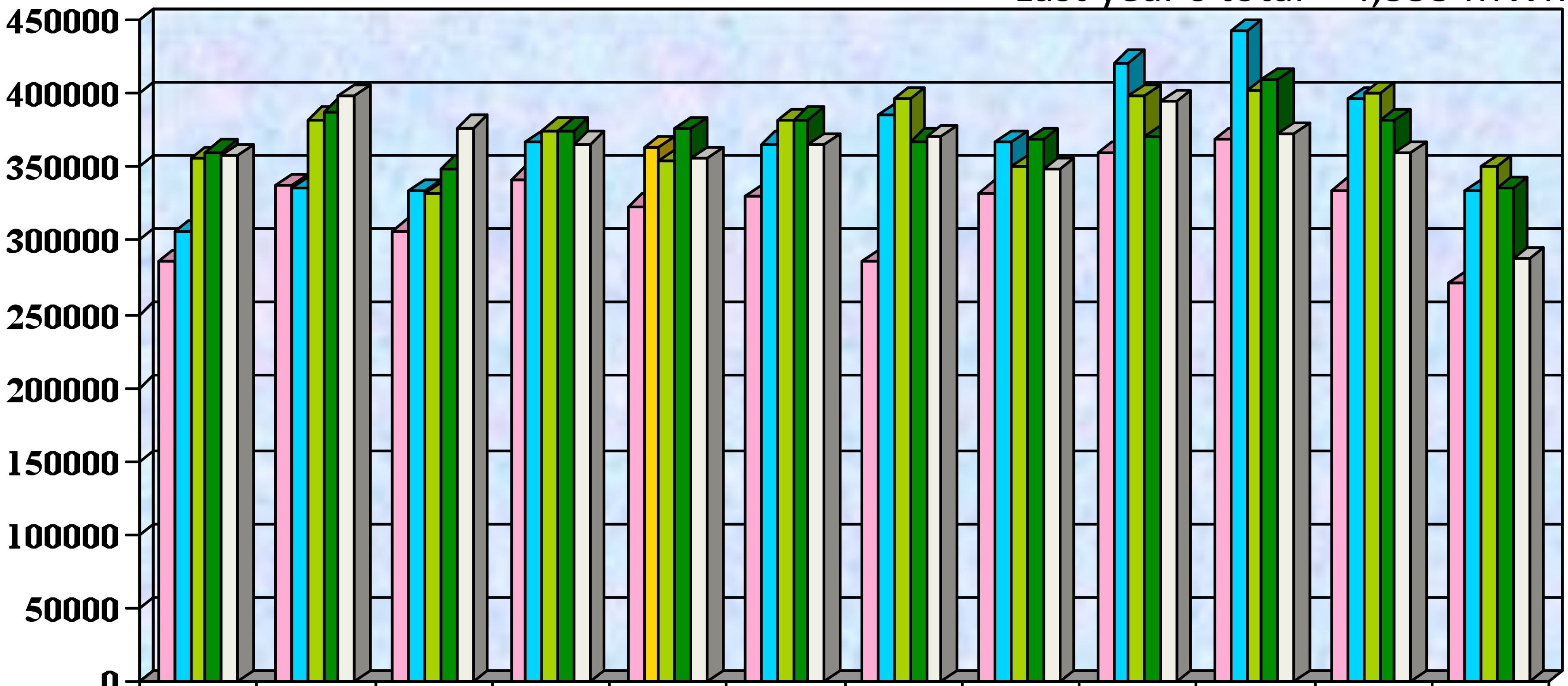
The report is structured with critical data gathering at the beginning, such as energy and water consumption, weather data and the like; followed by a review of previous work, such as XCO2; a review of technologies; thermal modelling and finally, results.

The final report, the first draft of which will be issued in early October, will take the form of a written report rather than this presentation format.

Carbon footprint and historic energy usage
Monthly electricity consumption (kWh)

The Carbon Advisory Service Ltd.

Last year's total = 4,355 MWh



	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APRIL	MAY	JUNE
2004-2005	286604	338072	307196	342088	323847	329864	286513	333088	360042	369283	334973	270678
2005-2006	306708	336339	334392	367155	363160	366151	385655	367382	421458	443013	396900	334000
2006-2007	356634	382796	332411	375577	354322	382521	397257	350743	398245	401921	400453	350228
2007-2008	360538	388456	349808	375238	376648	382789	367912	369489	371389	409179	381670	336314
2008-2009	358329	399216	377153	366247	355472	364677	370887	348217	394878	372538	360377	287355

2004-2005 2005-2006 2006-2007 2007-2008 2008-2009

Carbon footprint and historic energy usage
Monthly diesel consumption (litres)

The Carbon Advisory Service Ltd.

Last year's total = 1.2m litres

	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APRIL	MAY	JUNE
2004-2005	83341	100475	90529	100296	98835	98423	86877	98423	113544	109260	99348	82053
2005-2006	90159	98399	98194	102104	101947	103839	104764	101488	117331	124274	110368	93049.3
2006-2007	100552	106189	92683.6	104967	101401	107740	110150	100743	113773	115160	111998	95960.5
2007-2008	99410.1	109102	95308.5	103823	105196	105859	101473	102542	107092	113725	106827	91026.7
2008-2009	94797.8	111744	105811	100228	101025	100559	100172	95948.9	109438	103542	98748.7	80967

2004-2005 2005-2006 2006-2007 2007-2008 2008-2009

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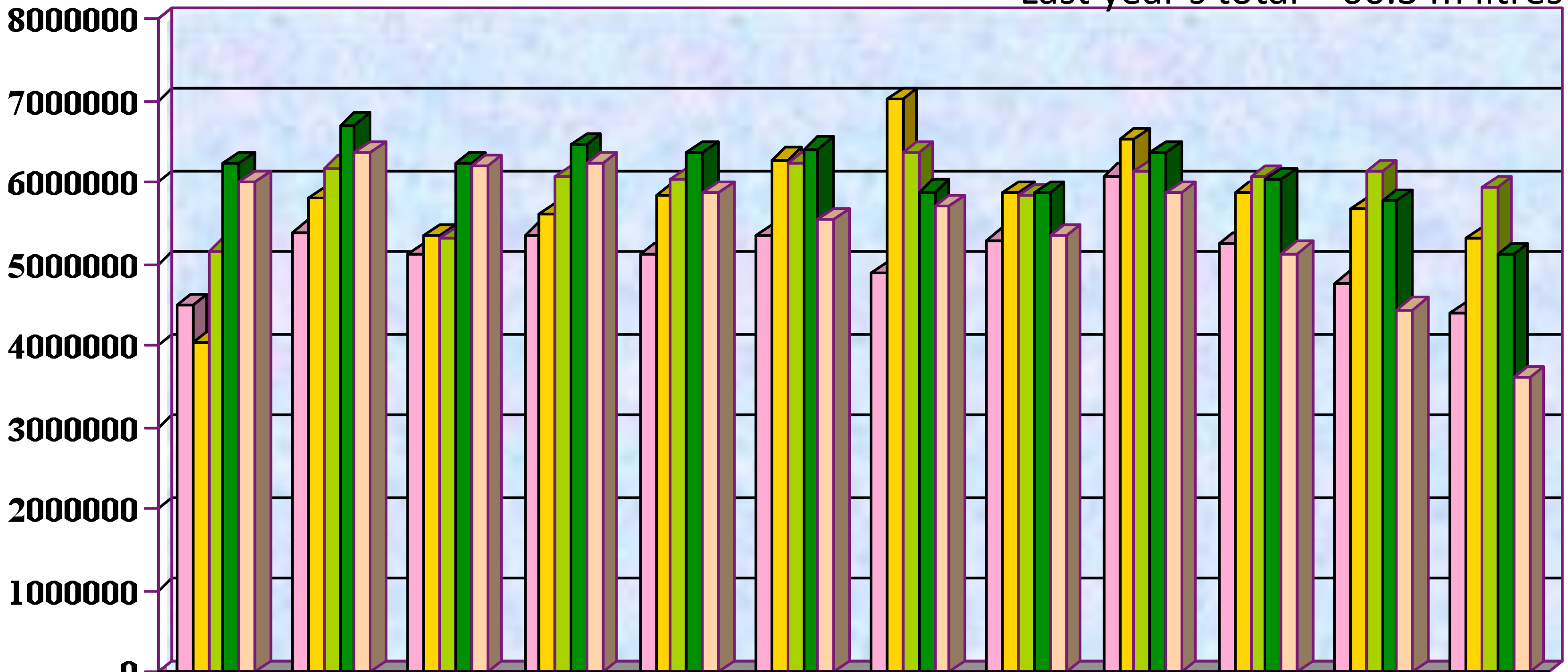
Carbon footprint and historic energy usage
Monthly water consumption (litres)

Last year’s total = 66.3 m litres



	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE
2004-2005	4488300	5396100	5116500	5361000	5108800	5356100	4876900	5297900	6082300	5253800	4771000	4383300
2005-2006	4044000	5806400	5335000	5613900	5844200	6278550	7028800	5883200	6535200	5883300	5678000	5321000
2006-2007	5165000	6178800	5322100	6074600	6033200	6231000	6357200	5827000	6129900	6068800	6126900	5934500
2007-2008	6224700	6706400	6228300	6471700	6351000	6413200	5887400	5867200	6352400	6027700	5774900	5119400
2008-2009	6005400	6367900	6198600	6221700	5872450	5541000	5715500	5348500	5865600	5135500	4446500	3597500

2004-2005 2005-2006 2006-2007 2007-2008 2008-2009

Carbon footprint and historic energy usage
Principal CO_2 emissions and parameters

The Carbon Advisory Service Ltd.

Parameter	Value
Embodied carbon of water	4.13 kg.CO_2 per m^3
Annual water consumption	66, 316,000 litres
Annual electricity consumption	4,355 MWh
Annual diesel consumption	1,203,000 litres
CV diesel: 10.9 kWh/litre. Therefore	13,113 MWh
Carbon emission factor for diesel	0.265 t.CO2/MWh
Annual carbon emission for diesel generators	3,475 t.CO2
Electrical carbon emissions factor	0.80 kg CO_2/kWh

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Carbon footprint and historic energy usage
Carbon Foresight's audit with CAS revisions/comments

Emission sorce	**Quantity**	**Unit**	**kg CO_2(e) per unit**	**Total t.CO_2(e)**	**Comment** *(note CF denotes Carbon Foresight)*
Long haul flights (> 5,000 km)	73,573,708	km	0.21014	15,461	
Medium haul flights (1,000 to 5,000 km)	3,977,769	km	0.18677	743	
Short haul flights (<1,000 km)	963,162	km	0.33070	319	
Coal (Charcoal)	10,136	kg	2.317	23	
Diesel (elect excl. RO plant)	1,100,729	L	2.680	2,950	CF used 342,047 litres for the whole site
Ethanol	6,066	L	1.470	9	
Petrol	135,851	L	2.315	314	
Jet fuel (seaplane)	2,049,189	L	2.530	5,184	Check figure
LPG	50,925	L	1.530	78	
Non-vegetarian meals	329,255	units	1.75000	576	CF listed a factor 1000 times smaller
Vegetarian meals	329,255	units	1.25000	412	CF listed a factor 1000 times smaller
Long haul air freight	1,508,462	t x mean km	0.57	860	
Short haul air freight	68,580	t x mean km	1.58	108	
Sea freight	4,075,669	t x mean km	0.013	53	
Office paper (0% recycled content)	2,465	kg	2.528	6	
Office paper (100% recycled content)	1,009	kg	1.790	2	
Tissue paper	2,405	kg	1.000	2	
Landfill (mixed solid waste)	149,104	kg	0.120	18	
Organics dumped at sea	368,759	kg	0.060	22	
On-site desalination/RO plant	66,316	m^3	4.1323	274	CF used 82,736,550 m^3 note 1
Total	**NA**	**NA**	**NA**	**27,415**	**CF had total of 24,963 difference due to diesel**

Note 1. This made no difference to the calculations because Carbon Foresight allowed the emissions under diesel

CAS has reviewed Carbon Foresight's audit to identify any anomalies. The diesel consumption used in the audit are much lower than the figures CAS has received from Six Senses.

Carbon footprint and historic energy usage
Carbon Foresight's audit with CAS revisions (graphical)

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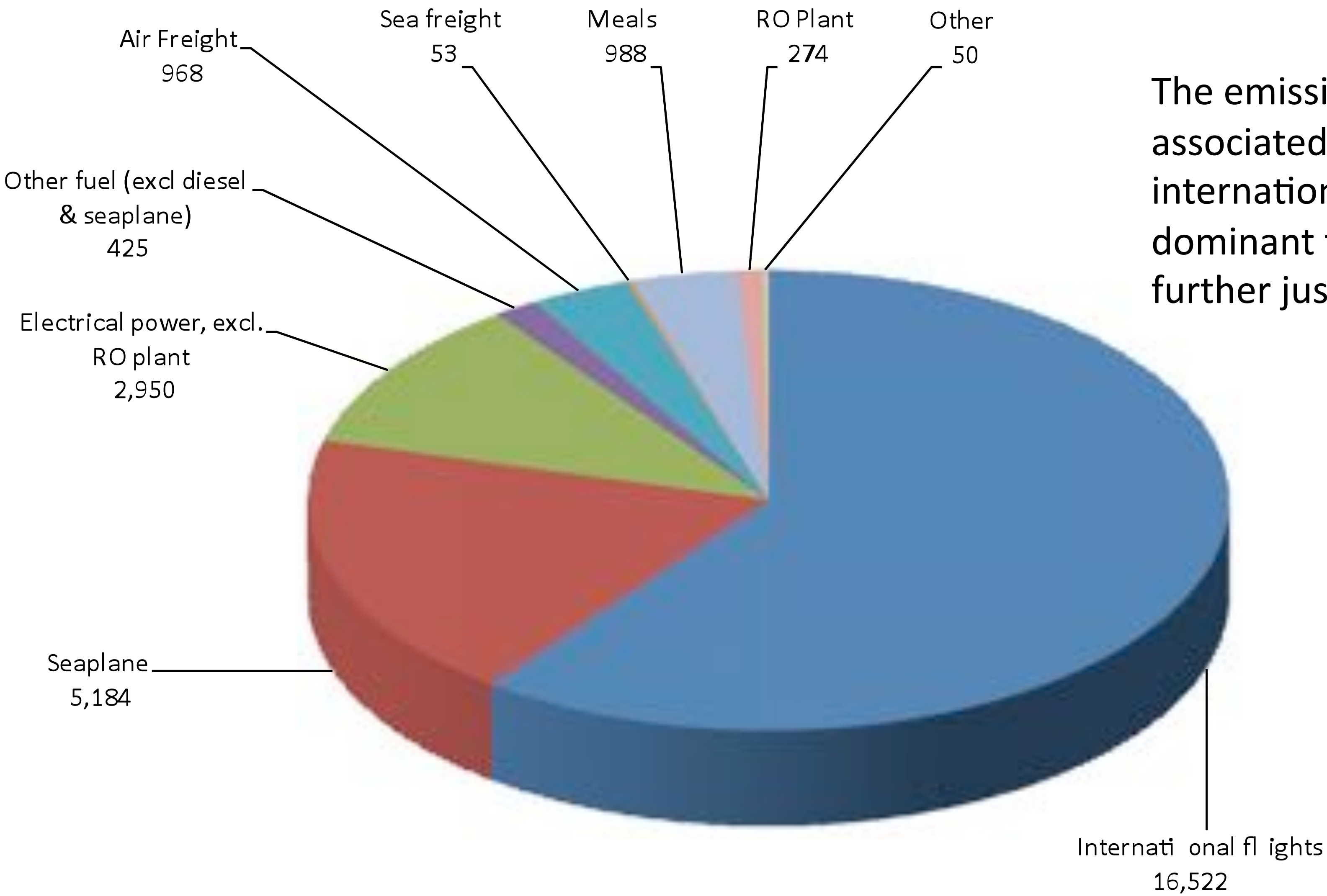

The emissions associated with international flights is so dominant that it needs further justification

Annual emissions, CO_2 equivalent (tonnes)

Weather analysis

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Three sources:

• hourly-annual weather data file for Minicoy (c.335 km north)

• hourly-annual weather data file for Male' airport, excludes global radiation (c.113 km south)

• XCO2 graphical and tabular data for Soneva Fushi, excludes wet-bulb temperature

Location map of all three islands for final report

Weather analysis, XCO2's measurements

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- **October 2006 to April 2008**

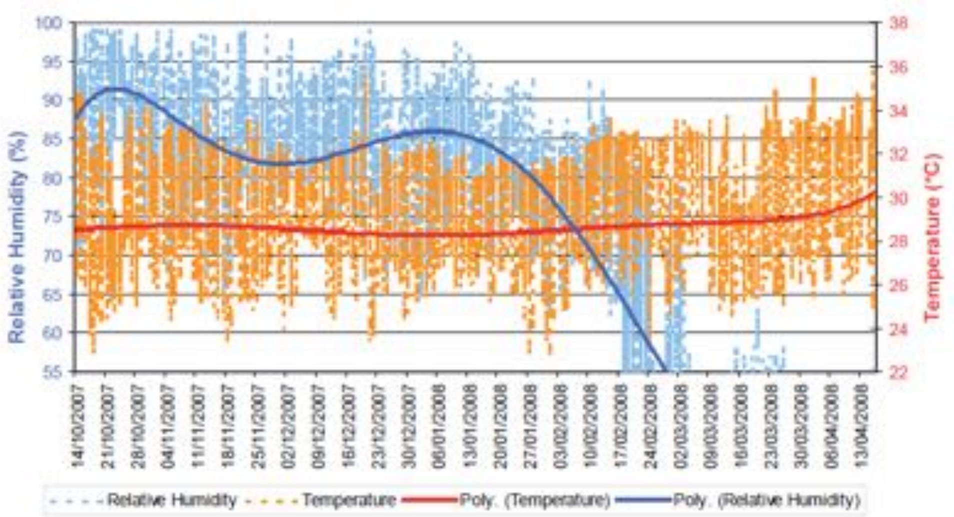
- **Measured:**
  - – wind speed and direction
  - – dry-bulb temperature
  - – relative humidity
  - – global radiation

- **Concerns with data:**
  - only one sensor per parameter
  - measurements only for 18 months
  - birds have "interfered" with wind speed measuring – what else?
  - obvious defect with RH sensor, could other sensors be wrong too but less dramatically?
  - Questionable global radiation data
  - No wet-bulb data – essential for evaporative cooling analysis

XCO2's measurements, problems with data

The Carbon Advisory Service Ltd.

"The wind speeds from the Vegetable Garden appear to have been affected by birds' interference with the sensors, both in terms of speed frequencies and overall averages."



"The data shows one clear abnormality after February 2008, when relative humidity falls and remains below the 50% level."

Could there be other abnormalities that are less obvious?

Usually weather data uses a number of sensors over up to 10 years. It is better to have precise data from Minicoy or Male' than questionable data from the island.

Main weather data comparisons

Weather parameter	Soneva Fushi (XCO2)			Minicoy			Male' Airport		
	High	Low	Mean	High	Low	Mean	High	Low	Mean
Dry-bulb, °C	36	24	29	34	21	28	32	23	29
Wet-bulb, °C	no data	no data	no data	29	20	25	29	21	26
RH, %	98	55	83	100	55	82	100	50	80
Global radiati on, horiz.	1720	kWh/m²/yr		2245	kWh/m²/yr		no data	kWh/m²/yr	
Global radiati on, incl at 6 deg.	no data	kWh/m²/yr		2278	kWh/m²/yr		no data	kWh/m²/yr	

• Excellent dry-bulb and RH correlation between Minicoy (c.335 km north), Male' Airport (c.113 km south) and Fushi (XCO2)

• Excellent wet-bulb correlation between Minicoy and Male' airport

• Global radiation for Soneva Fushi is much lower than that for Minicoy, despite Fushi being slightly nearer the equator. This could only be true if Fushi was much cloudier than Minicoy, say if it were mountainous – which it clearly isn't.

• Earth Link are using 1,927 kWh/m²/yr for their PV calculations, this being the estimate for Male', but we have precise measurements for Minicoy of 2,278 (at 6 degrees tilt). As before, Fushi must be at least this figure (typically).

• Only the Minicoy weather file has all of the data we need

Conclusion: use the Minicoy weather file.

Minicoy weather analysis

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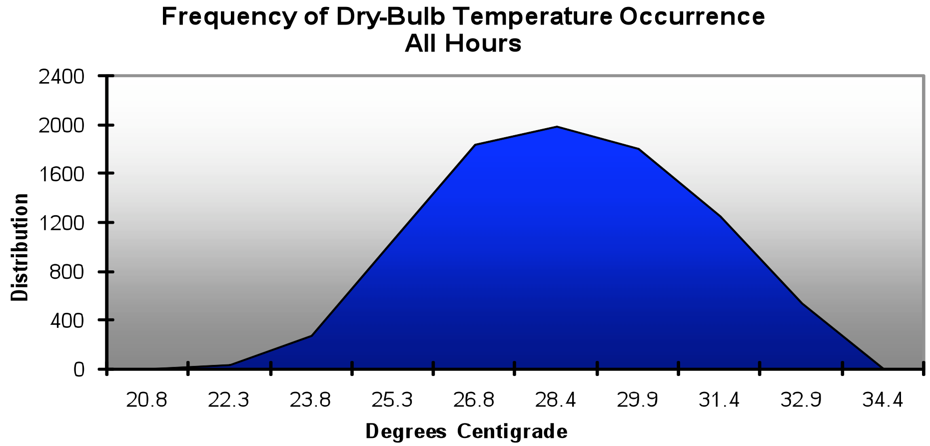

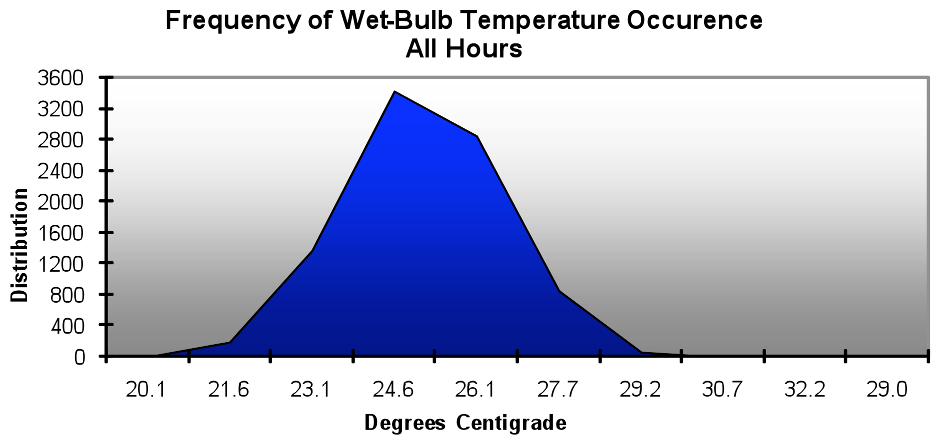

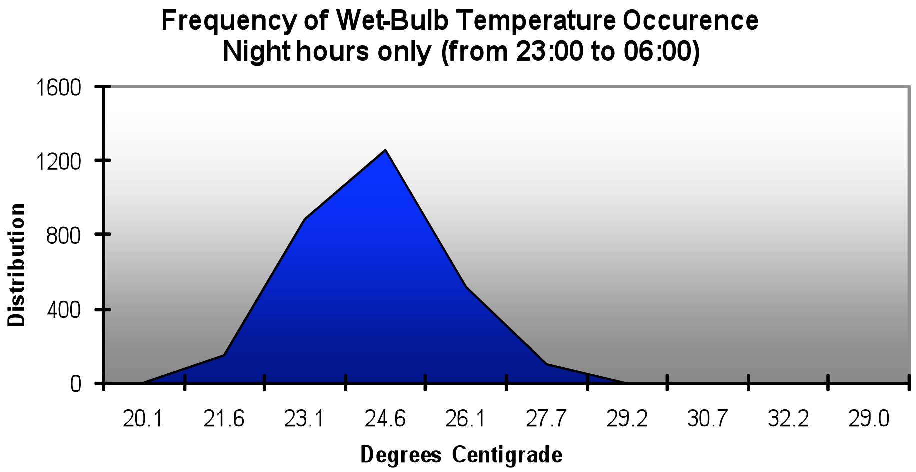

The graph above is showing that the absorption chillers could operate without the deep seawater pipe, but the cooling towers would have to be quite large and the heat source quite hot

Technology reviews
Wind, Soneva Fushi (XCO2 report)

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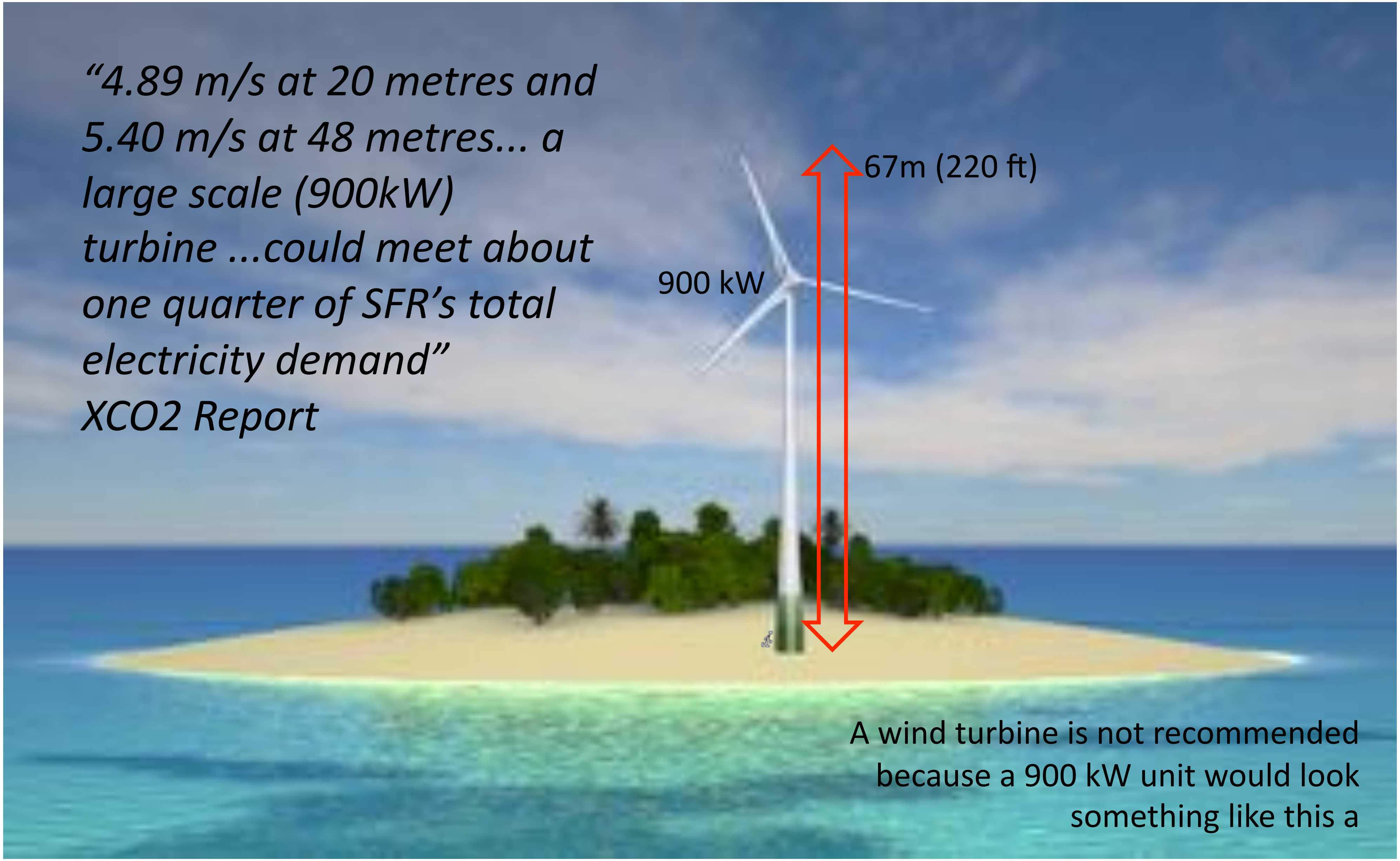


Technology reviews
PV, principal details

- Annual global irradiation on surface (c. 2,278 kWh/ m^2)
- Seasonal average efficiency, 10.4% (TBC)
- Electronic losses, 15% (TBC)
- Module area, 750 m^2
- Total electrical generation (PV), 151 MWh p.a.
- Last year's total, 4,355 MWh
- PV contribution, 3.5% of annual electricity generation (this percentage will increase as demand is reduced)

Technology reviews
PV, embodied energy

The Carbon Advisory Service Ltd.

- **Embodied carbon of PV modules – information awaited**

- **Clearing of forest to accommodate PV**
  - 1,500 m^2 (0.15 hectares) of forest cleared.
  - Embodied CO_2 per hectare = 550,000 kg
  - 82,500 kg CO_2 released
  - For 20 year obsolescence period, 4125 kg CO_2 / yr

- **Concrete bases**
  - 36 @ 900mm x 900mm x 800mm deep
  - Total volume = 23.3 m^3.
  - Embodied carbon of concrete = 183 kg CO_2 per m^3
  - Embodied carbon of concrete bases = 4,264 kg CO_2
  - For 20 year obsolescence period, 171 kg CO_2 / yr

- **Annualised embodied CO_2 emissions**
  - TBC + 4125 kg + 171 kg = TBC + 4,296 kg

- **Annual CO_2 emissions reduction**
  - 151 MWh at 800 kg CO_2 / MWh = 120,800 kg CO_2

- **Annual CO_2 reduction**
  - 120,800 – (TBC + 4,296) awaiting information but say 116,504 kg CO_2 per year.

3.3%

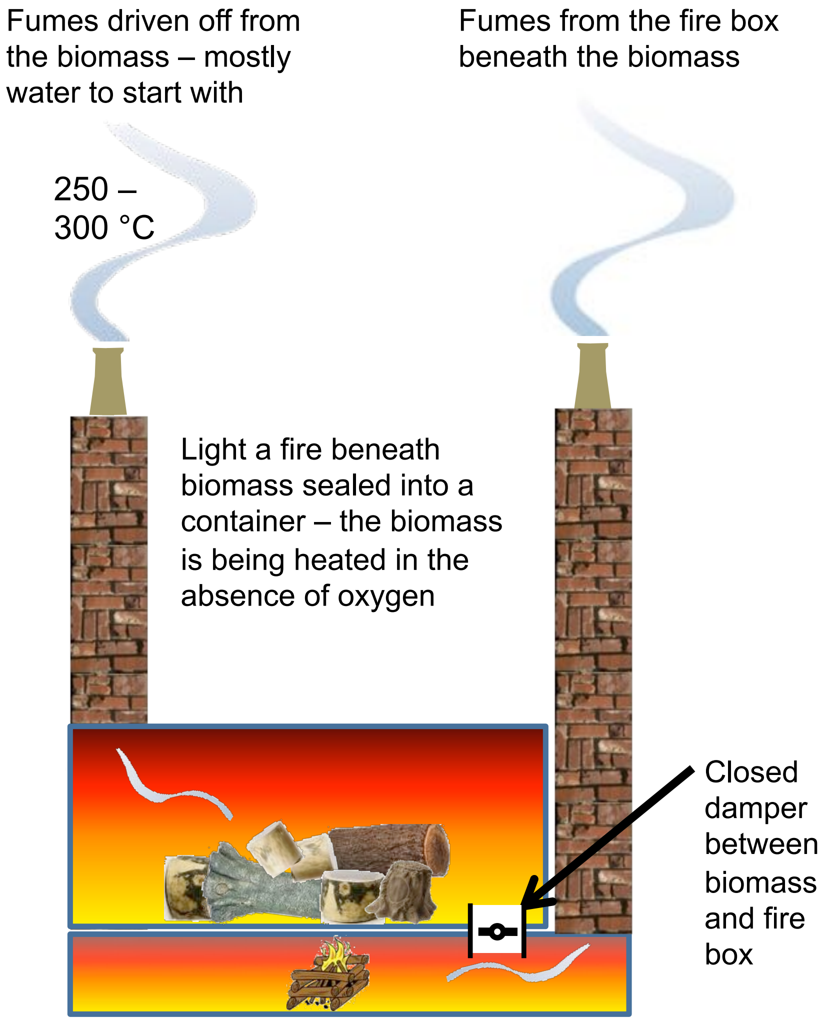
Technology reviews
Biochar data sheet

The Carbon Advisory Service Ltd.

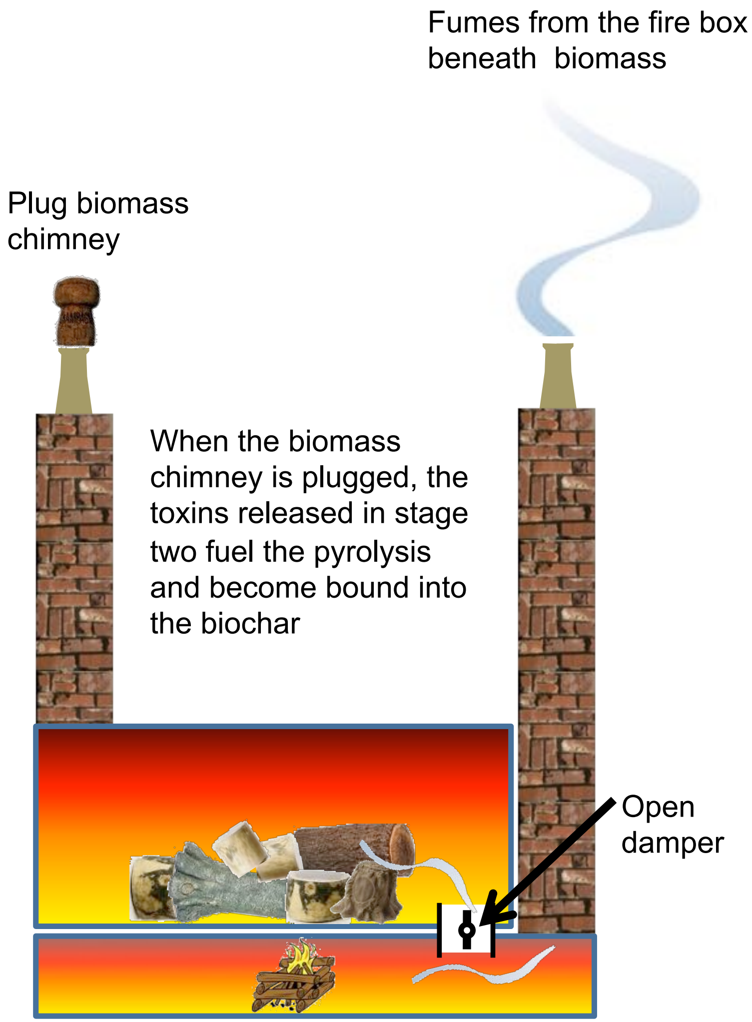
- Mostly for timber waste
- 500 kg (wet) 250 kg (dry) per day – conservative estimate
- Biochar production = one third dry weight of biomass
- Calorific Value, dry timber = 5 MWh / tonne
- Carbon content = half dry biomass (x 3.67 for CO_2)
therefore 1,835 kg CO_2 per 1,000 kg dry biomass
- Half CO_2 is bound into biomass and half lost to atmosphere

Technology reviews
Biochar, process diagrams

The Carbon Advisory Service Ltd.



Stage one, 8 hours



Stage two, 4 hours

Technology reviews
Biochar, carbon equation

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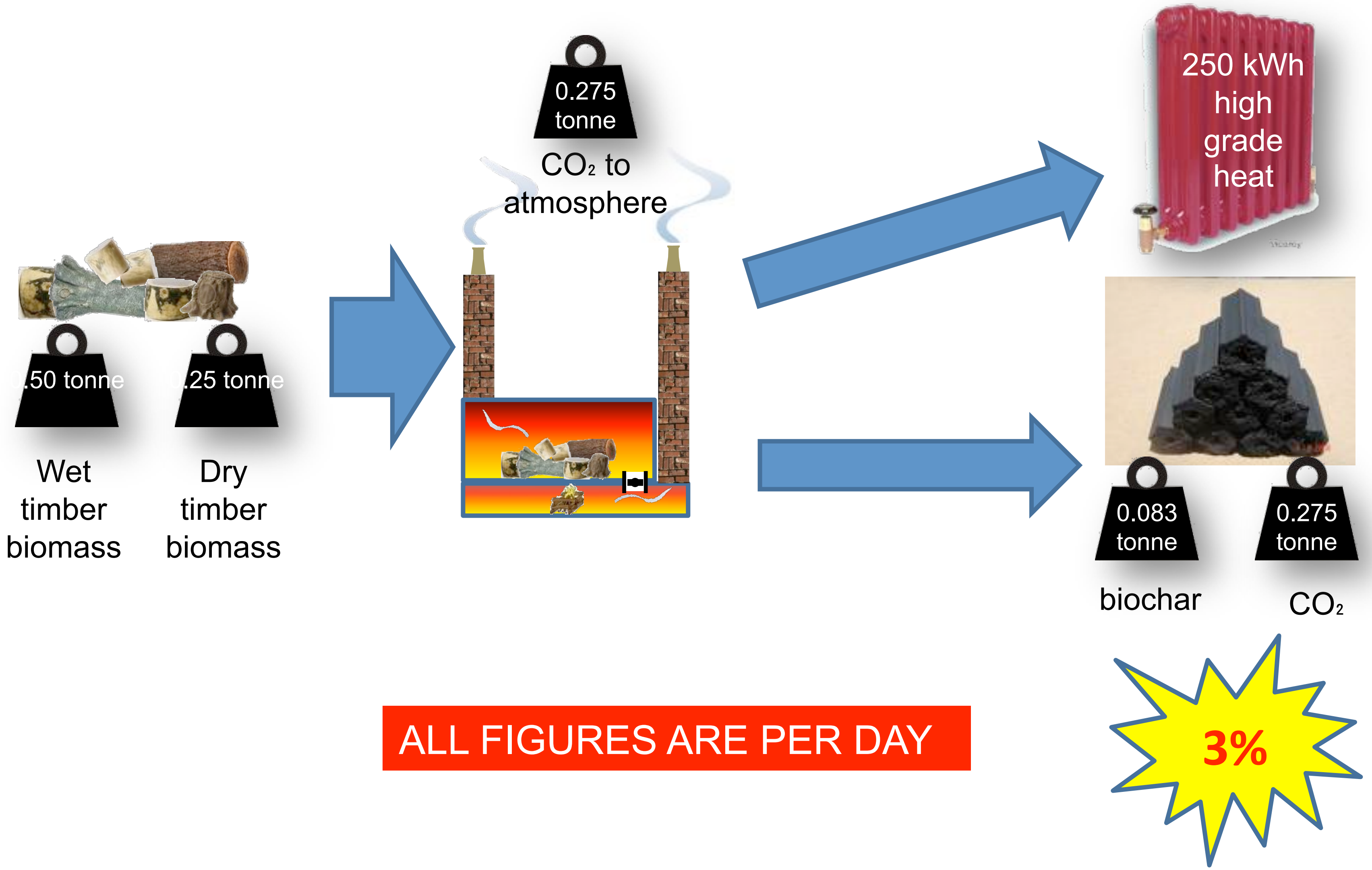


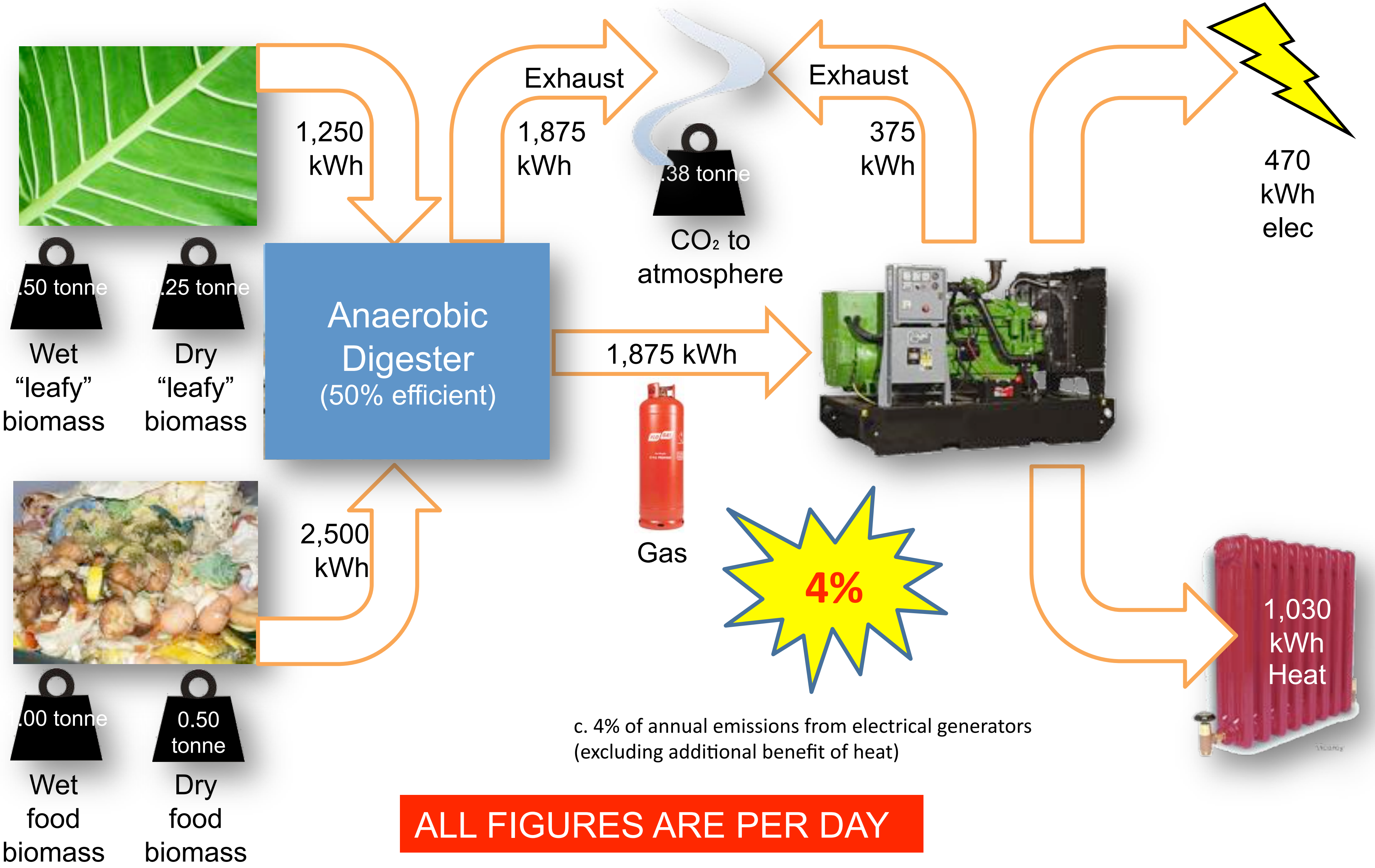
c. 3% of annual emissions from electrical generators (excluding additional benefit of heat)

Technology reviews
Anaerobic digester data sheet

- For organic waste, i.e. “leafy” biomass and food waste
- “Leafy” biomass, 500 kg (wet) 250 kg (dry) per day – conservative estimate
- Food waste, 1,000 kg (wet) 500 kg (dry) per day – conservative estimate
- Carbon content = half dry biomass (x 3.67 for CO_2) therefore 1,835 kg CO_2 per 1,000 kg dry biomass
- Calorific Value (dry organic waste) = 5 MWh / tonne
- Typical efficiency of digester (energy in, gas out) = 50 to 80%

Technology reviews
Anaerobic digester, energy and carbon equations

The Carbon Advisory Service Ltd.



c. 4% of annual emissions from electrical generators
(excluding additional benefit of heat)

ALL FIGURES ARE PER DAY

Technology reviews
Bamboo sequestration calculations

The Carbon Advisory Service Ltd.

- CV = 4,000 kcal/kg (16,747 KJ/kg)

- 1 MW = 0.26 kg/s bamboo (at 23% electrical efficiency)

- **50** tonnes biomass per acre p.a.

- 10 acres were allocated, therefore 500 tonnes of bamboo harvested per year

- 1 tonne bamboo sequestrates **1.47** tonnes CO2

- **50** x **1.47** = 74 tonnes CO2 per acre p.a. (740 tonnes CO_2 for whole island)

- Estimated emissions, whole site excl. transport c.3,475 t.CO_2

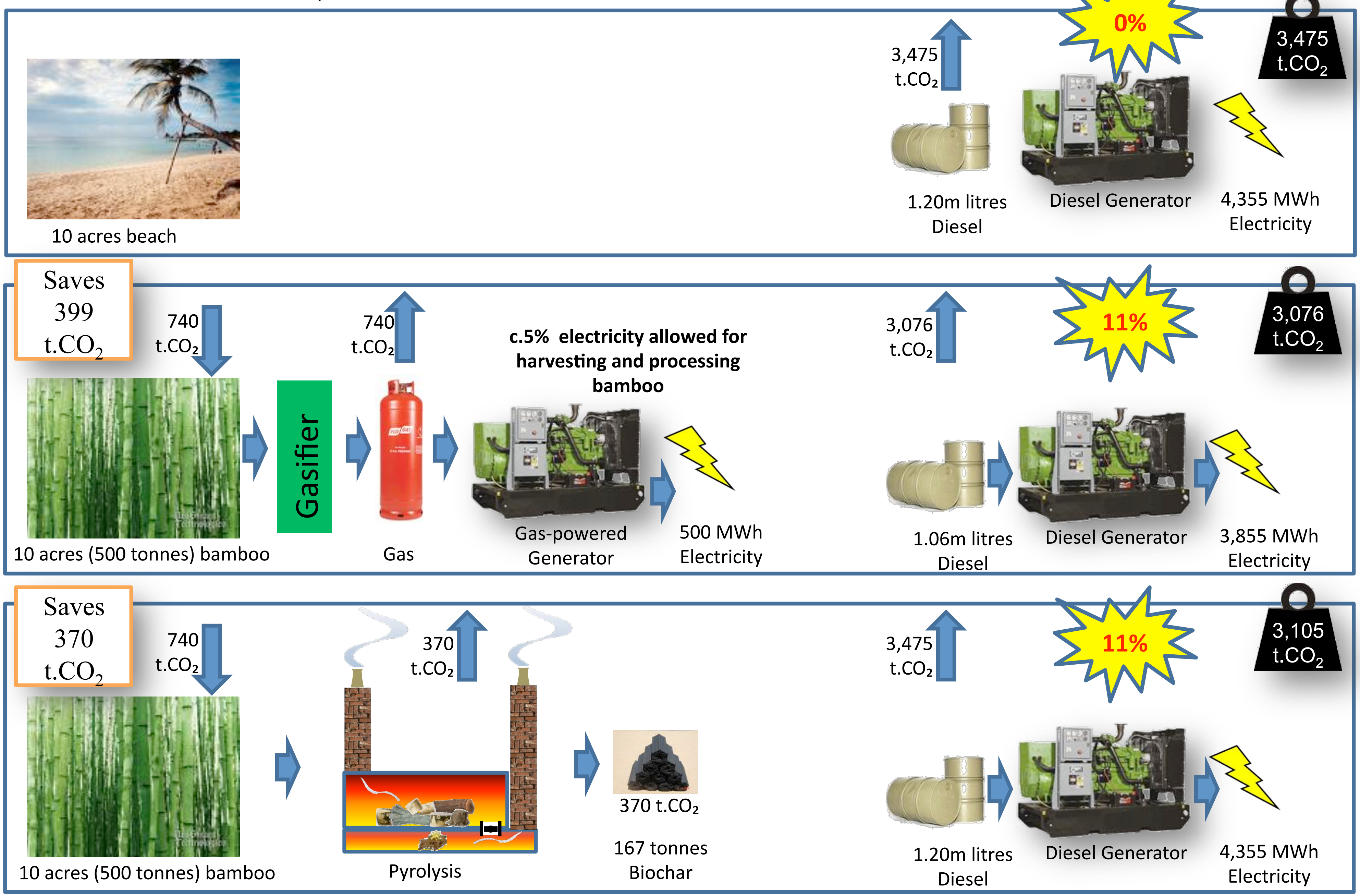
- 740 tonnes of CO_2 per year is circa 23% of emissions from on-site electricity

- Harvested period: 9 months per year, which means:
  13 tonnes per week, or
  320 kg/hr assuming 40-hour working weeks

Technology reviews - Bamboo options

The Carbon Advisory Service Ltd.

Options. Top: existing diesel generation, no bamboo. Middle: displace diesel with gasified bamboo. Bottom: Diesel as currently but biochar bamboo



Technology reviews
Bamboo, summary

The Carbon Advisory Service Ltd.

- The 10 acres allocated for bamboo is dense forest which would have to be cleared. This would significantly reduce the carbon abatement benefits and could have an adverse impact on the island's biodiversity.

- Electricity from bamboo has a very similar carbon saving capacity as biochar from bamboo, but creating biochar is a much simpler and cheaper process.

- An option is to grow and gasify or pelletise the bamboo offsite where space could be at less of a premium (40 hectares have been discussed in India for example), and import the gas for use in the generators. This avoids having a potentially noisy, industrial process on the resort, but care must be exercised to avoid the biofuels debate vis-a-vis displacing food crops and the like.

- There is also the opportunity for a small on-site demonstration project.

Technology reviews
Beema Bamboo, references

The Carbon Advisory Service Ltd.

Info taken from Dr. Barathi's presentation
BEEMA Bamboo
CV = 4000 kcal/kg (16,747 KJ/kg)
1 MW = 1,000 kJ/s. Assuming 23% elect efficiency, 4,348 kJ/s (bamboo) = 1 MW (elec)
4,348 kJ/s (bamboo) = 0.26 kg/s bamboo

1MW power plant:
200 acres of cultivation area
9,000 tonnes biomass p.a. (**45 tonnes biomass per acre p.a.**)

75 tonnes biomass in first 10 years (**7.5 tonnes biomass p.a**. mean)
110 t.CO_2 sequestrated, equivalent to 50,000 litres oil (check)
(1.47 t.CO_2 sequestrated per tonne biomass)
(at 45 t. Biomass p.a. per acre at 1.47 t.CO_2 per t. biomass, then 66 t.CO_2 p.a. per acre.)

8 poles per plant
1000 plants per acre
7 kg/pole
Therefore **56 t. biomass per acre per year**

Info taken from Dr. Barathi's email dated 28th July 2009
80 to 85 tonnes of CO_2 p.a. per acre

Info taken from Dr. Barathi's email dated 30th July 2009
50 tonnes biomass per acre p.a.

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Technology reviews
Absorption (waste heat-driven) cooling

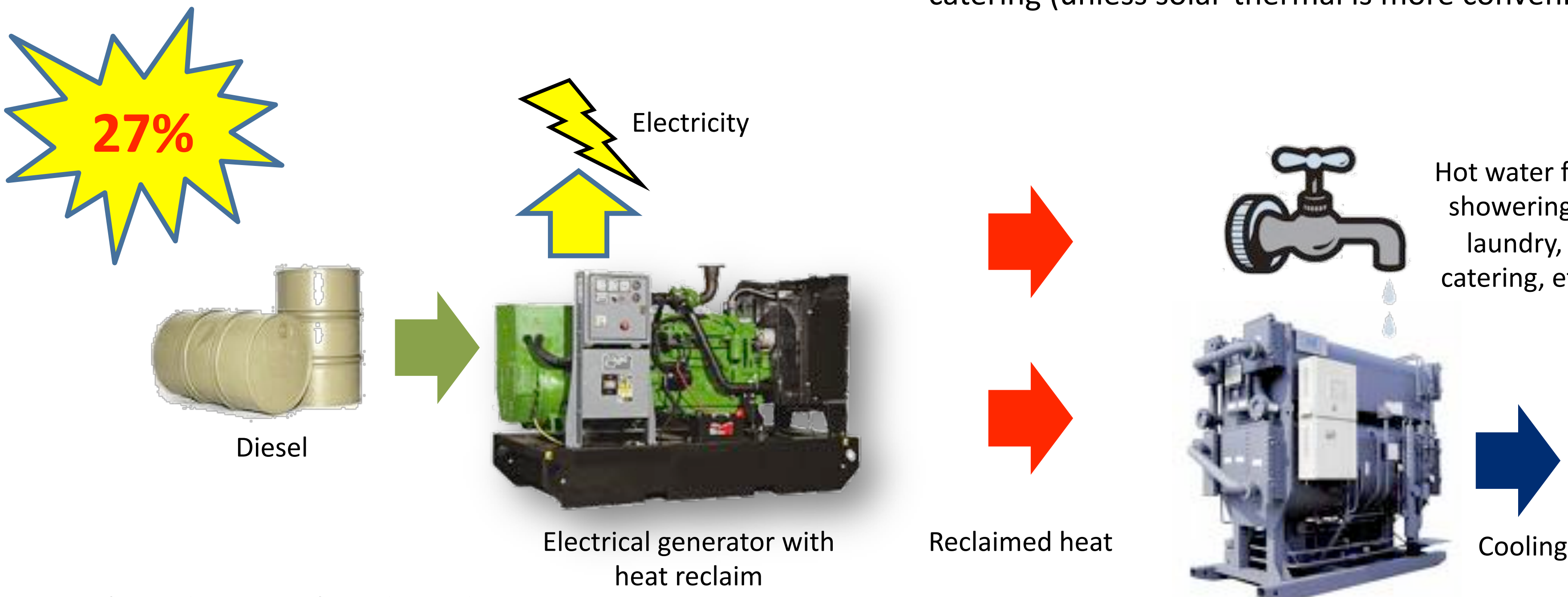
Absorption cooling has been popular in industrial applications for at least 50 years. Refrigerators used in caravans and powered by bottled gas also use this technology. In principle, the overall thermodynamic cycle is the same as a conventional chiller but the motive power is heat rather than electricity.

The thermodynamic process is quite complex but the basic principle here is that "free" heat, say from electrical generators, is supplied to the unit to produce cooling.

When heat is reclaimed from an electrical generator in this way, it is called a "Combined Heat and Power" (CHP) unit.

At the temperatures typically available from electrical generators, each 1 kW of waste heat should generate about 0.8 kW of cooling.

The waste heat of the electrical generators should also meet the domestic hot water loads, including those for catering (unless solar-thermal is more convenient).



c. 27% of annual emissions from electrical generators

Technology reviews
Tidal power

Text has not been provided for this technology at this stage

Technology reviews
Off-site wind / Guest transport offsets

An off-site wind farm is used to claim offset of guests' travel emissions. A review of this will be included in the final report.

Thermal modelling
Host buildings, method

Cooling is likely to be the single largest electrical demand on the island, therefore the energy strategy will be effected by the simultaneous peak demand and profile.

Thermal modelling an island resort such as Soneva Fushi is especially challenging because the loads are very sensitive to human behaviour, which can only be estimated. The challenge is met by simulating the buildings over a range of likely behavioural traits, such as the operational hours of cooling, how many villas are let, etc.

It is important that the energy strategy is viable across the whole range of likely scenarios, it is less important to predict which scenario is closer to the real world, especially as the real world situation will be changing constantly.

The approach has been to model about 80% of the loads. The remaining 20% is distributed across a wide range of small buildings for which drawings and survey data are not available

With acceptable accuracy, this 20% is assumed to follow the same cooling profile as the modelled 80%.

Some buildings were taken to be representative of others, for instance the Dhondheeni has been taken as representative of all similar host accommodation, although it was modelled with both east-west and north-south orientations.

The next few pages give details of what has been modelled, which buildings have been treated as representative of others and the total number of each type of building.

The models will be finessed through the remainder of the Concept Appraisal and cooling design stage, so comments at this stage would be very helpful.

Thermal modelling
Guest residential summary

The Carbon Advisory Service Ltd.

Parameter	1 bed Crusoe	2 bed Crusoe	Soneva Fushi villa	Treehouse	The Retreat	Jungle Reserve	Rehendhi
Quantity	1 east side 1 west side	16 east side 4 west side	8 east side 16 west side	0 east side 1 west side	3 (Note1)	1 east side 0 west side	5 terrace 10 ends
Conditioned rooms	Lounge, bedroom	Lounge, bed 1, bed 2	Bed	Bed 1, bed 2	Lounge, bed 1, bed 2	Lounge, bed, spa, gym	bed
Conditioned area	79.2 m^2	122.0 m^2	30.0 m^2	58.3 m^2	81.4 m^2	91 m^2	25 m^2
Peak cooling load	4.7 kW east (59 W/m^2) 4.7 kW west (59 W/m^2)	6.4 kW east (52 W/m^2) 6.1 kW west (50 W/m^2)	2.7 kW east (91 W/m^2) 2.8 kW west (93 W/m^2)	4.4 kW (75 W/m^2)	9.8 kW (121 W/m^2)	8.4 kW (93 W/m^2)	0.9 kW terrace (36 W/m^2) 1 kW end (38 W/m^2)
Installed cooling cap.	7.0 kW	14.0 kW	10.5 kW	12.3 kW	17.6 kW	19.3 kW	3.51 kW
Annual cooling (if continuous)	10.3 MWh east 10.7 MWh west	13.8 MWh east 13.6 MWh west	7.7 MWh east 7.4 MWh west	12.2 MWh	34.1 MWh	19.8 MWh	1,3 MWH terrace 1.0 MWh end

Note 1: In fact there are only two of these; one on the east and the other on the west. A third was added to make allowance for the owners' villa for which no details have been found. The models for the Treehouse, Retreat and Jungle reserve are preliminary because they lack accurate elevation details, this in turn is because they were not available to be surveyed during the last site visit. Without accurate elevation details, there is no value in modelling the two different orientations.

Thermal modelling
Host buildings

The Carbon Advisory Service Ltd.

Host living accommodation, based on Dhondheeni

If oriented east-west,
cooling intensity is 56 W/m²
annual cooling is 185 kWh/m²

If oriented north-south,
cooling intensity is 49 W/m²
annual cooling is 152 kWh/m²

Using the site plan and floor area schedule, the following orientations were used:
9,149 m² east-west
2,178 m² north-south

Peak cooling load = 619 kW (whole resort)
Fan-coil schedule shows installed capacity of 411 kW
Annual cooling demand = 2,024 MWh (whole resort)

Office building, based on admin office

Peak cooling intensity = 80 W/m²
Annual cooling intensity= 162 kWh/m²
Total office space = 1,244 m² (whole resort)
Peak cooling load = 99.5 kW (whole resort)
Fan-coil schedule shows installed capacity of 103 kW
Annual cooling demand = 202 MWh (whole resort)

Retail, based on retail in admin building

Peak cooling intensity = 104 W/m²
Annual cooling intensity = 217 kWh/m²
Total retail space = 450 m² (whole resort)
Peak cooling load = 46.8 kW (whole resort)
Fan-coil schedule shows installed capacity of 60 kW
Annual cooling demand = 98 MWh (whole resort)

Thermal modelling versus Fan-coil schedule

The Carbon Advisory Service Ltd.

Load	kW
Fan-coil schedule, total connected load, all fan-coils	1,726
Fan-coil schedule, total connected load, fan-coils of buildings that were modelled, including those treated as similar	1,375 (80%)
Peak cooling load of modelled buildings	966
Estimated cooling load of buildings not modelled	193
Total estimated peak cooling load	1,159

We modelled a peak of 966 kW, the schedule shows 1,375 kW, so if the model is right, there is a margin of 42%

We estimated a peak of 1,159 kW, the schedule shows 1,726 kW, so if the model is right, there is a margin of 33%

Representative examples of buildings comprising 80 percent of the total fan-coil capacities were modelled and then applied, on a Watts per square metre basis to other similar buildings. Where appropriate, buildings were modelled in two different orientations.

It was assumed that the other 20% of buildings would follow the same cooling load profile.

Thermal modelling versus Fan-coil schedule

The Carbon Advisory Service Ltd.

Building type	Modelled kW	Schedule kW
Guest villas (see breakdown slide "Guest Residential Summary)	250	802
Host accommodation	619	411
Offices	100	103
Retail	47	60
TOTAL	**1,016 (Note 1)**	**1,375**

Note 1 – the actual modelled simultaneous peak is 966 kW. This is less than the sum of the individual peaks of each building type.

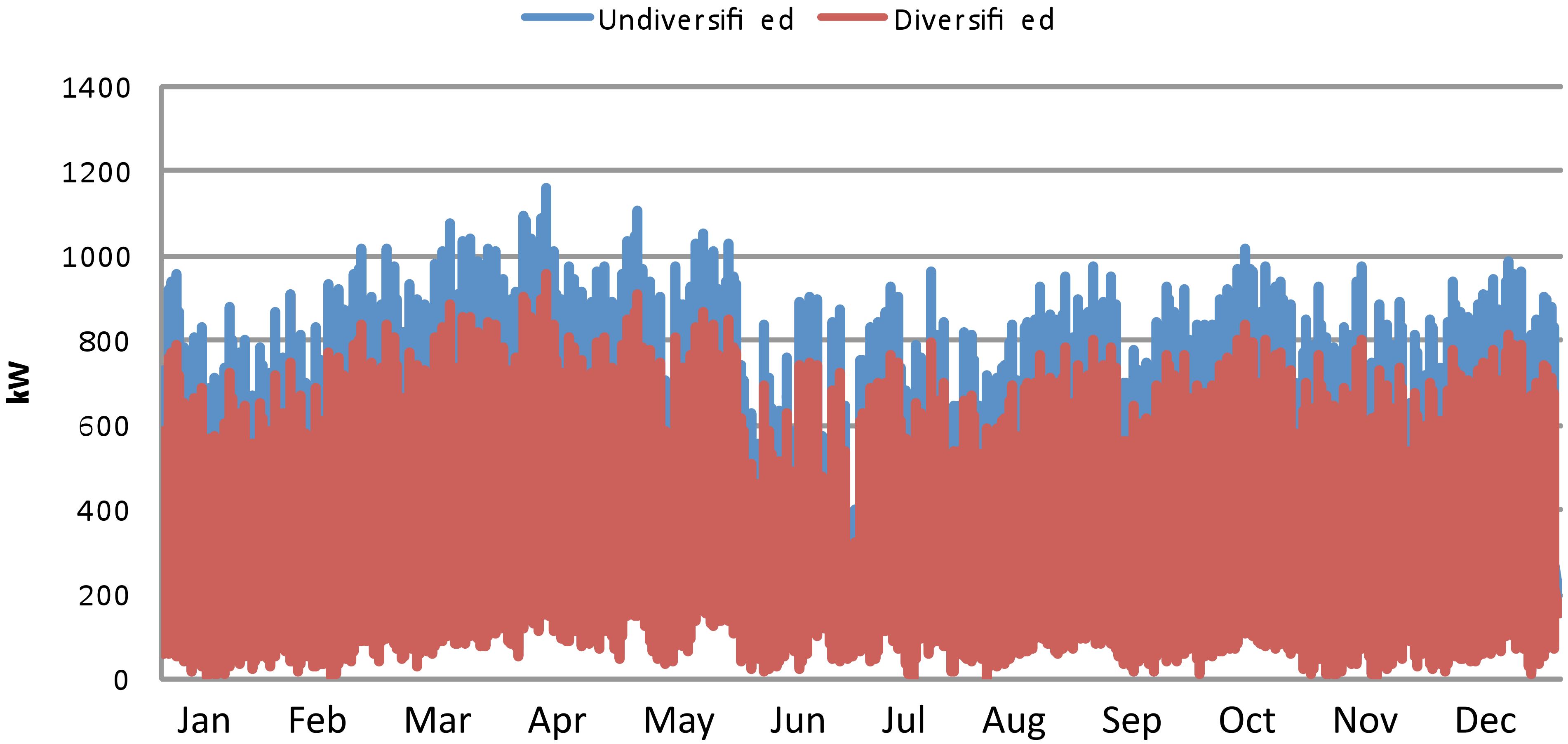
This table shows a comparison between the model and the fan-coil schedules for each building type modelled (i.e. Excluding the 20% not modelled).

The main differences are clearly the guest villas and host accommodation. The fan-coil schedules are showing that the guest villas have twice the cooling capacity for two thirds of the floor area. Notwithstanding the priority for guests' comfort, the disparity appears to be unusual.

Thermal modelling
Cooling loads for whole island for one year

The Carbon Advisory Service Ltd.

Annual totals
Undiversified = 3,538 MWh,
Diversified (80% for host and guest accommodation) = 2,902 MWh

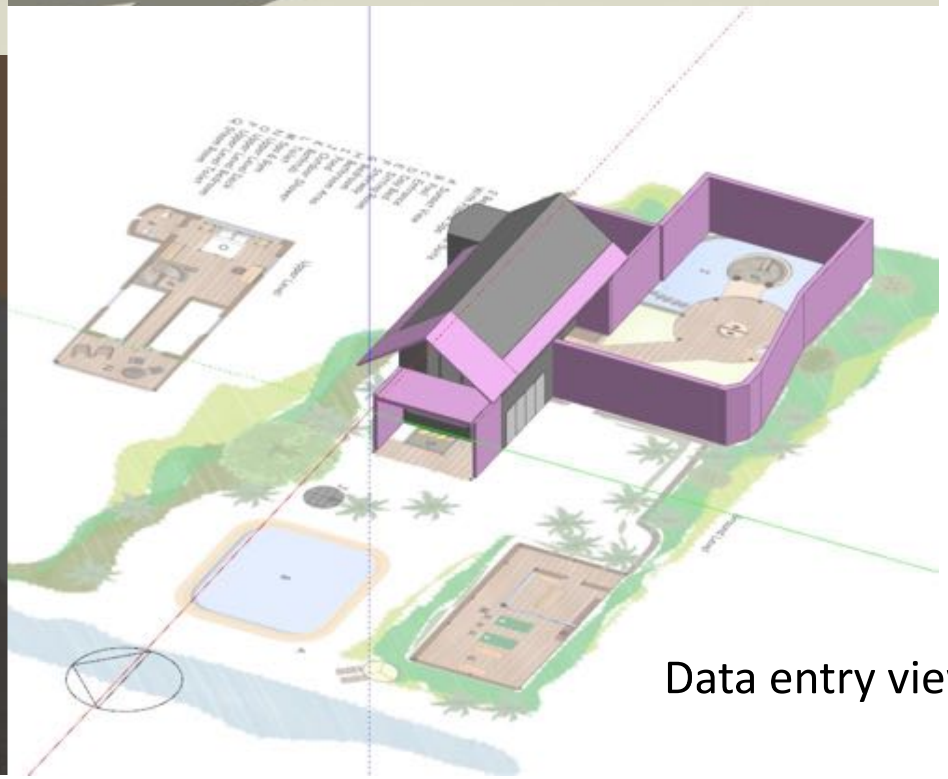


Thermal modelling graphics, Two bedroom Crusoe

The Carbon Advisory Service Ltd.

Two bedroom Crusoe, cont.

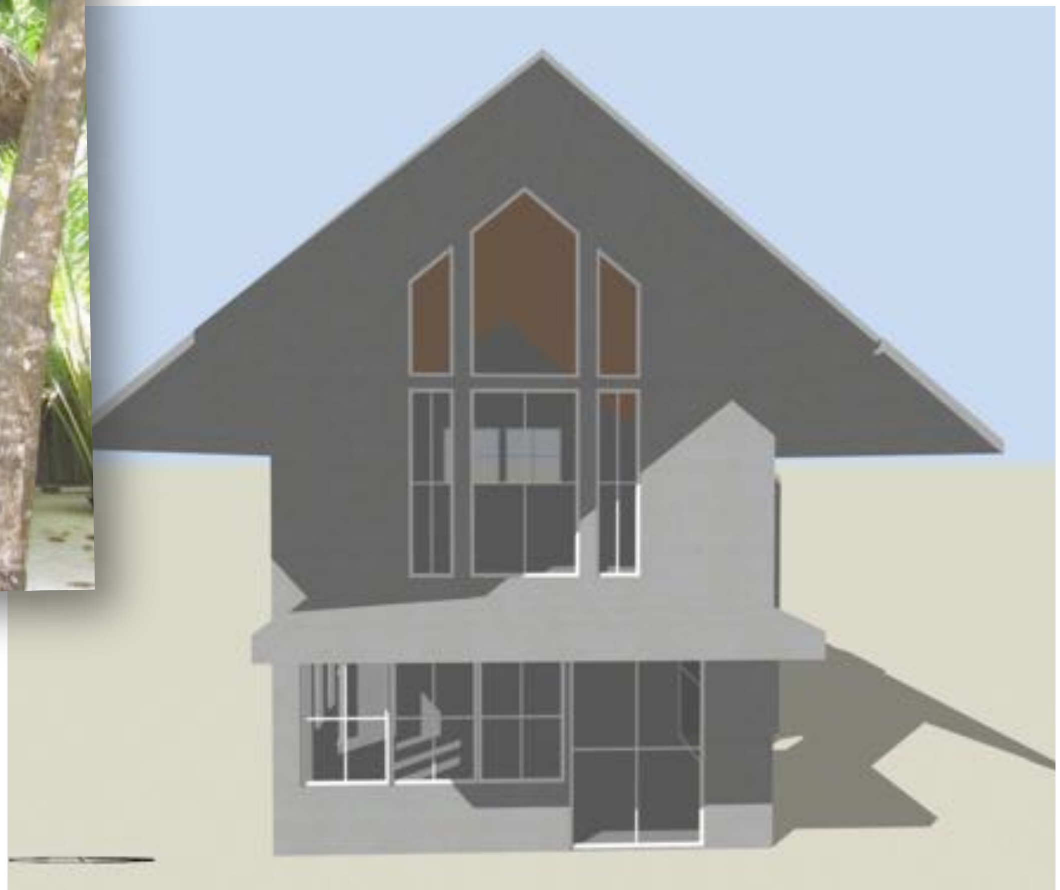
View from 1st floor bedroom towards the lightwells



Data entry view

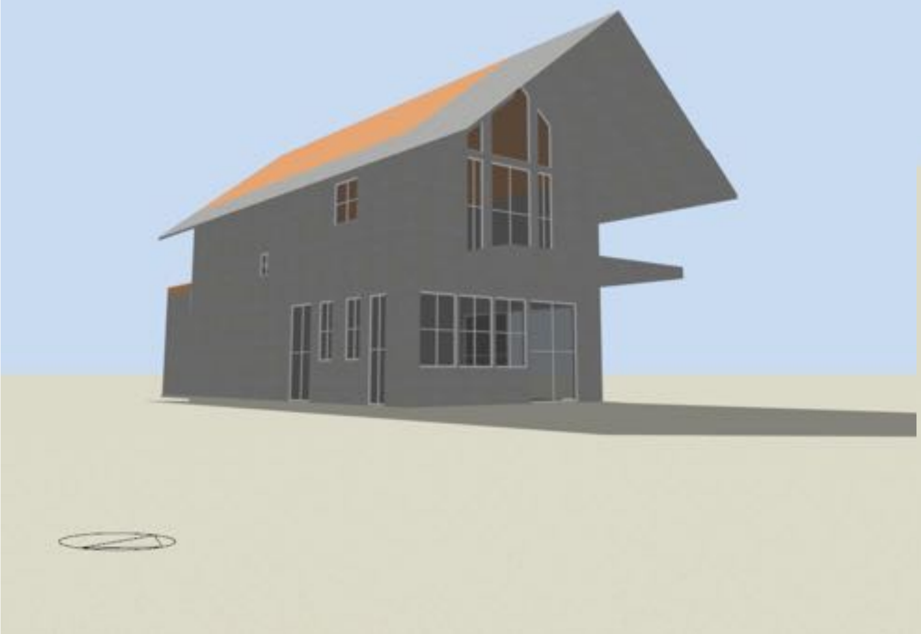
Thermal modelling graphics, One bedroom Crusoe

The Carbon Advisory Service Ltd.

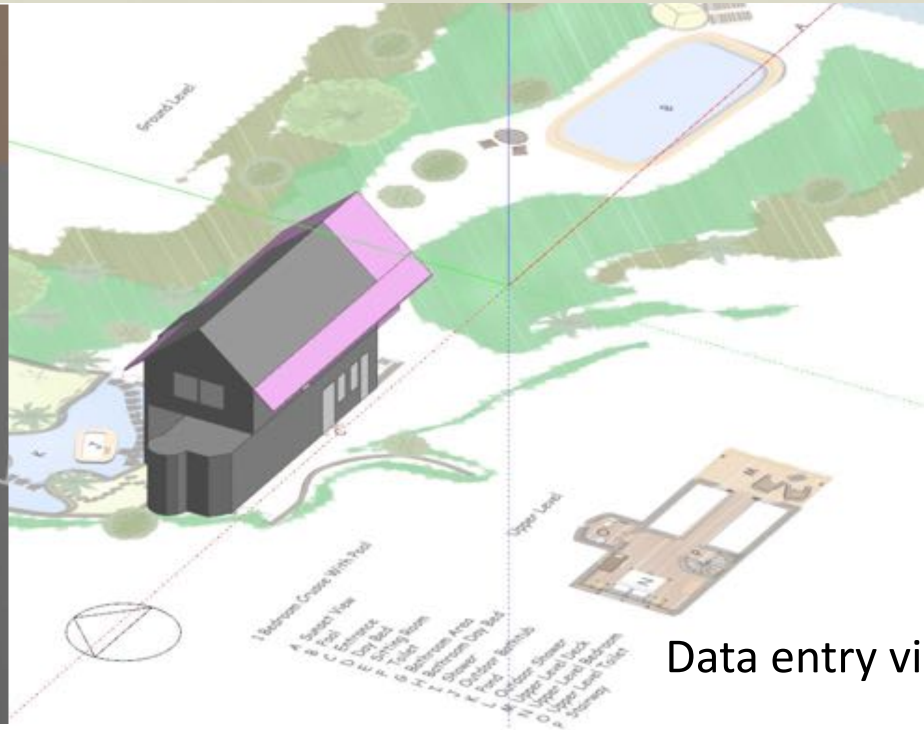


One bedroom Crusoe, cont.

The Carbon Advisory Service Ltd.



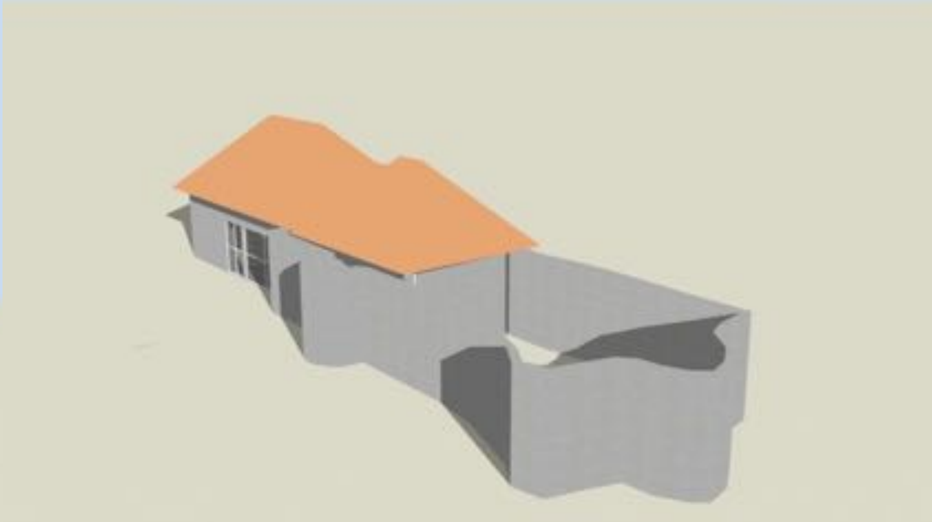
View from 1st floor bedroom towards the lightwells

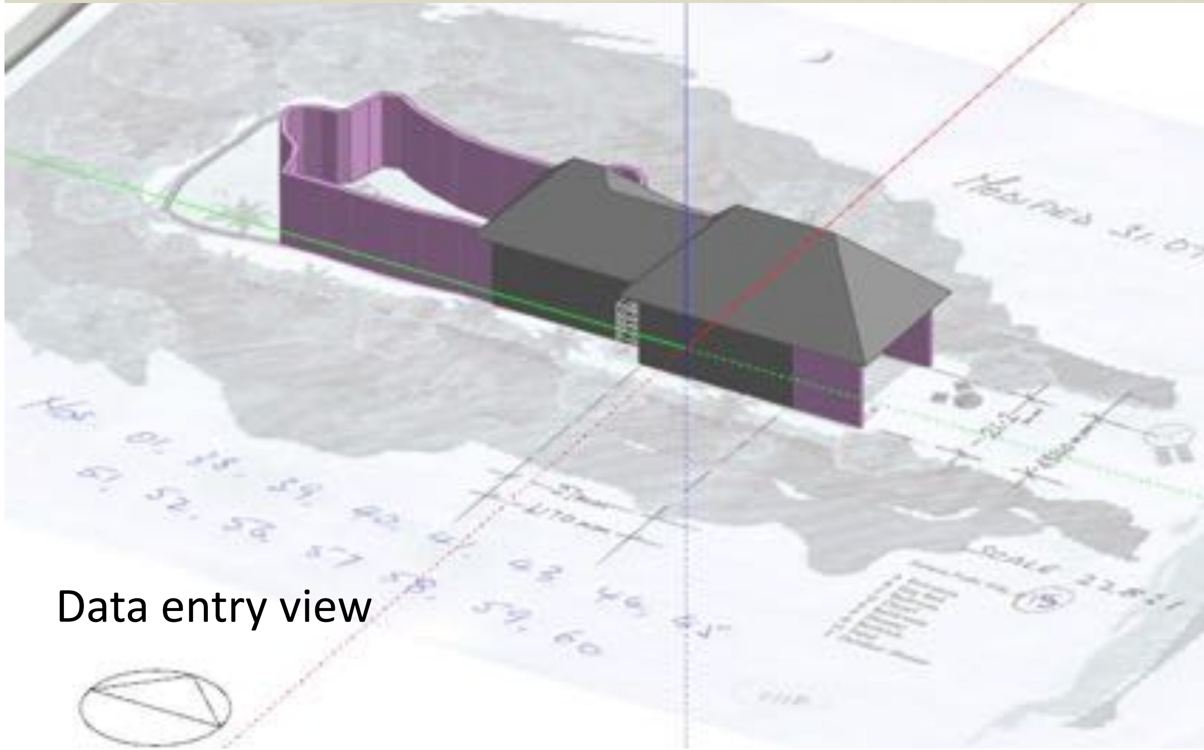


Data entry view

Thermal modelling graphics, Soneva Fushi villa

The Carbon Advisory Service Ltd.



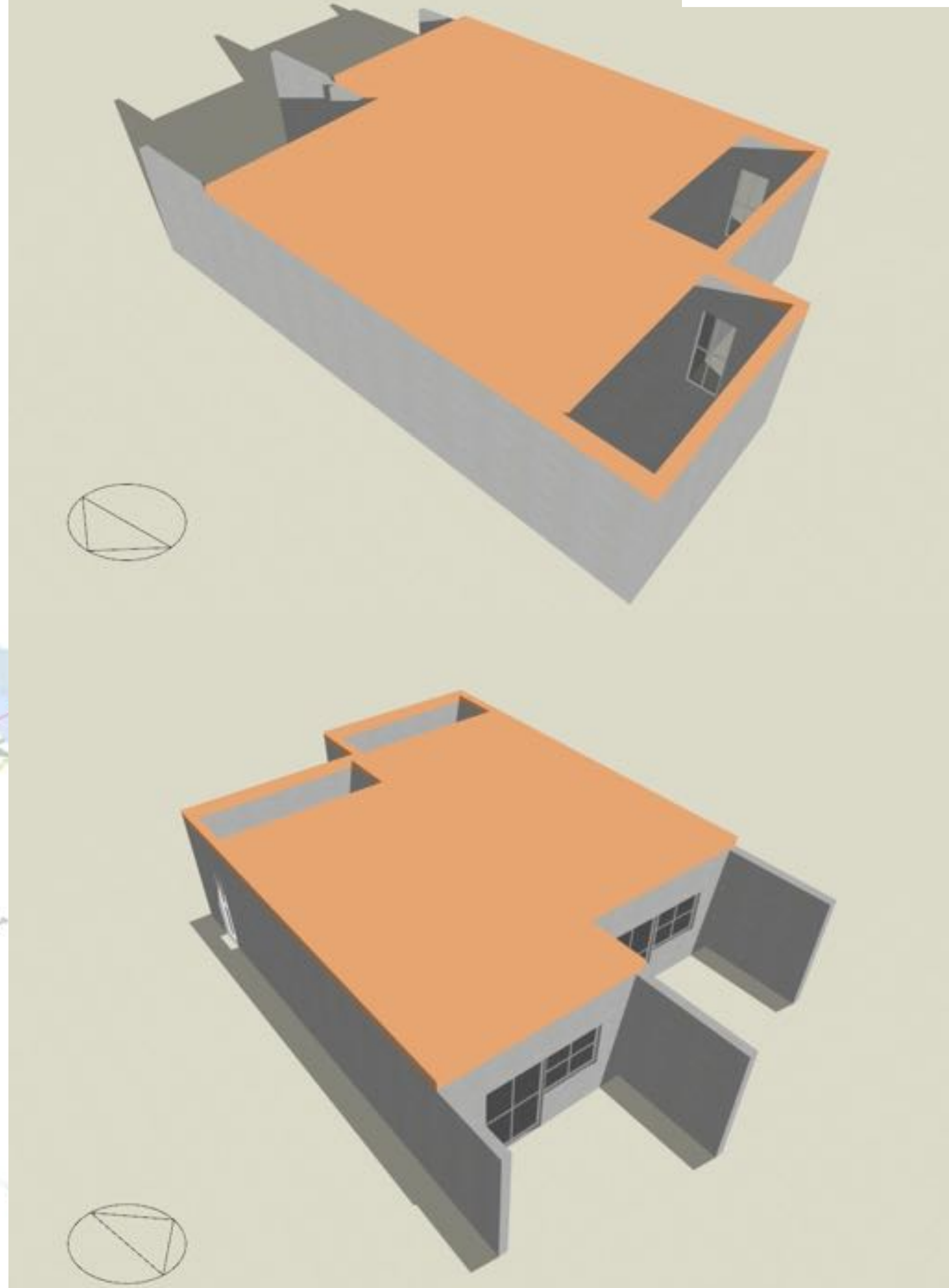


Data entry view

Thermal modelling graphics, Rehendhi

The Carbon Advisory Service Ltd.

Data entry view



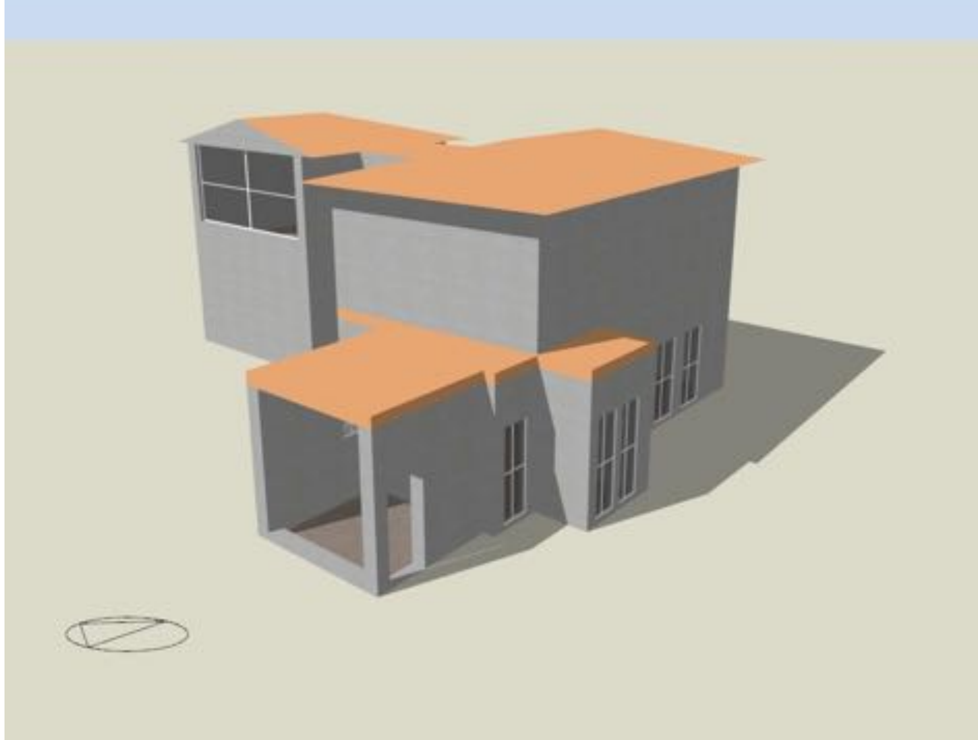
Thermal modelling graphics, Treehouse

The Carbon Advisory Service Ltd.

Unable to survey – elevations are estimates (TBC)

Thermal modelling graphics, Retreat

The Carbon Advisory Service Ltd.

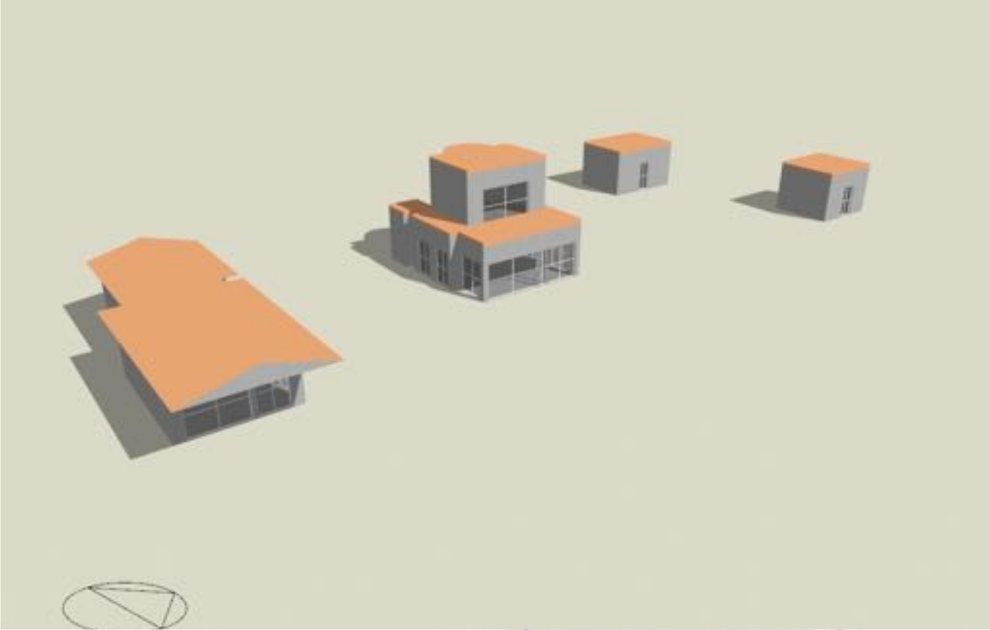


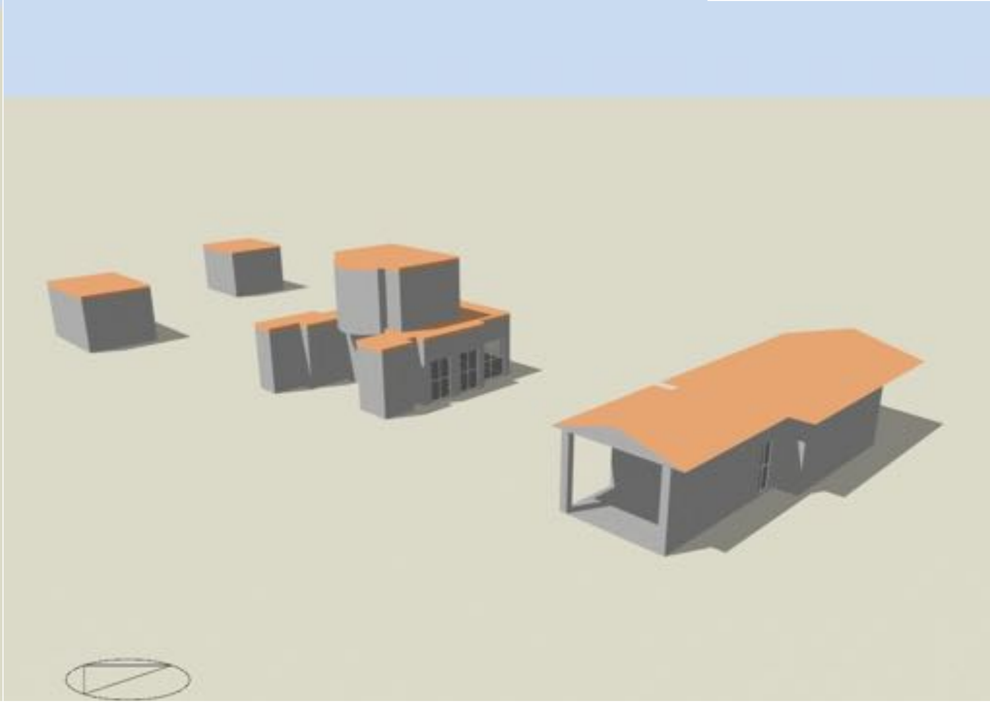
Unable to survey – elevations are estimates (TBC)

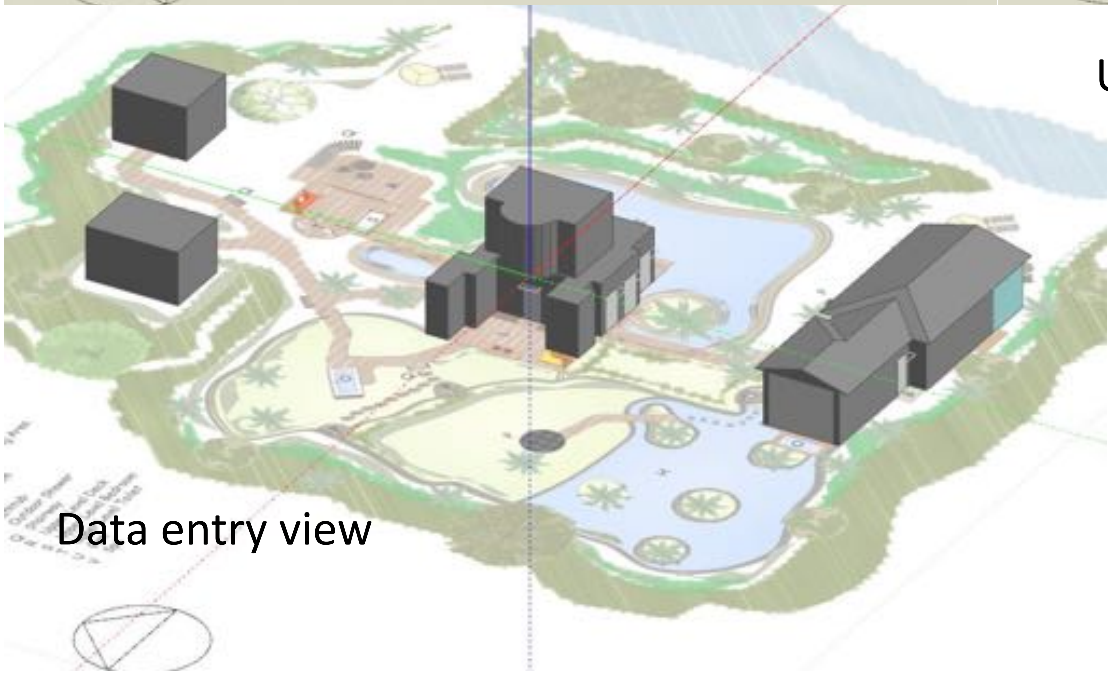
Data entry view

Thermal modelling graphics, Jungle Reserve

The Carbon Advisory Service Ltd.





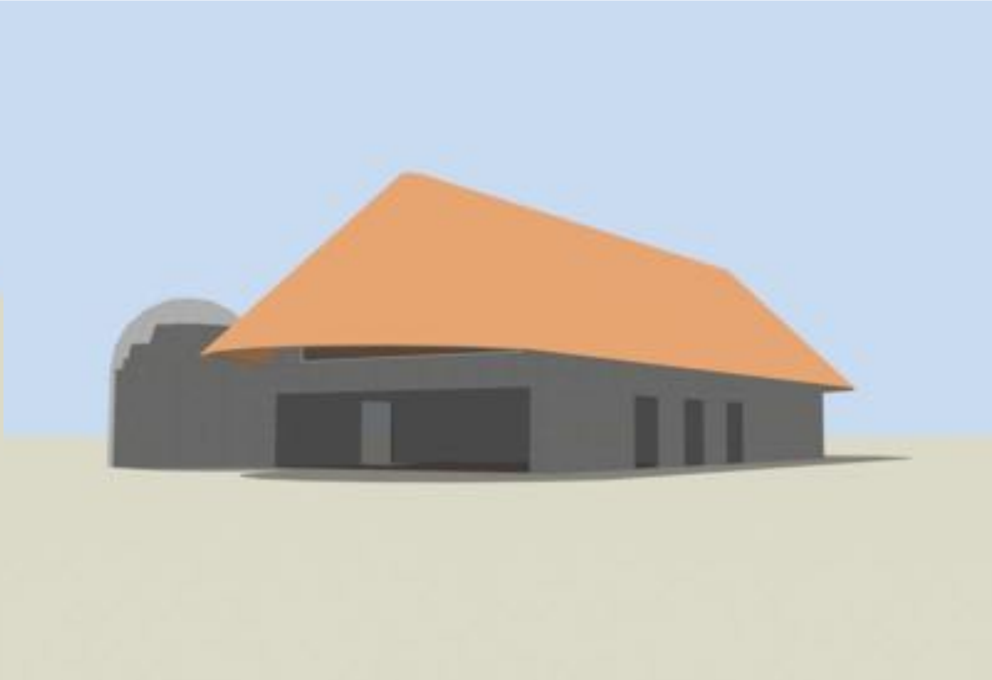


Data entry view

Unable to survey – elevations are estimates (TBC)

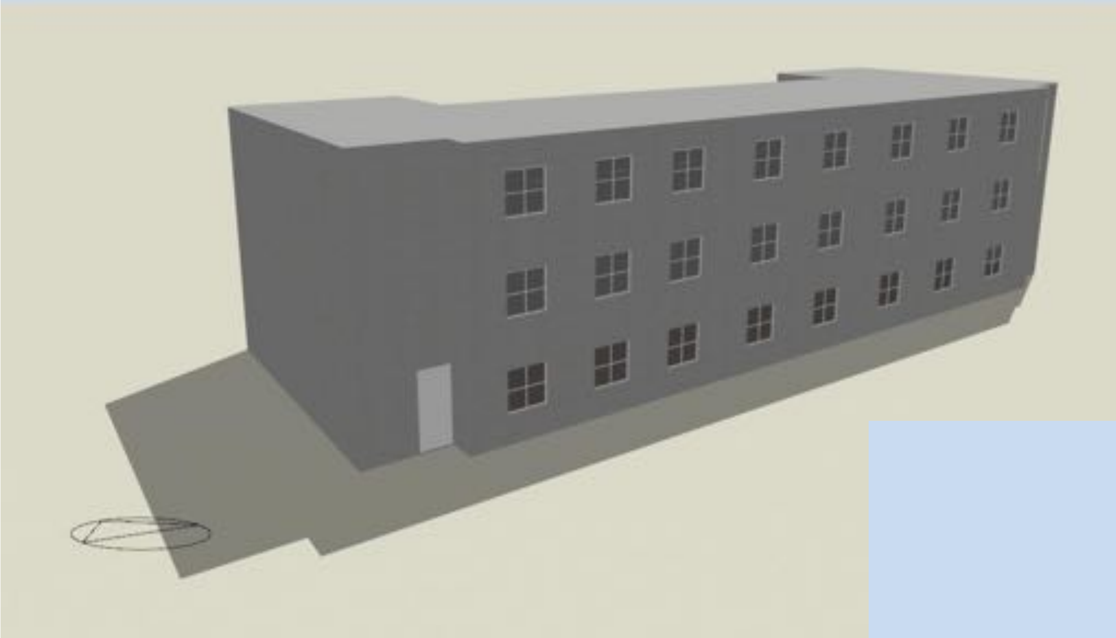
Thermal modelling graphics, Admin block and shop

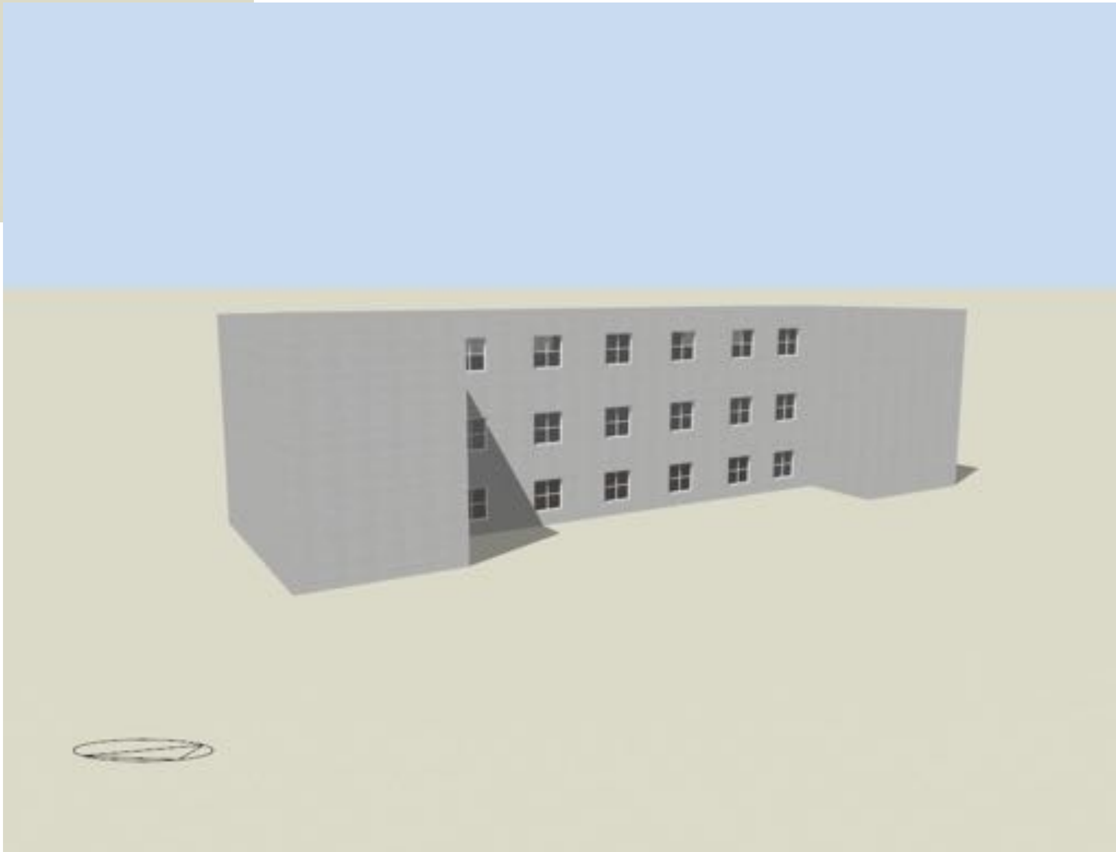
The Carbon Advisory Service Ltd.



Thermal modelling graphics, Typical host accommodation (Dhondheeni)

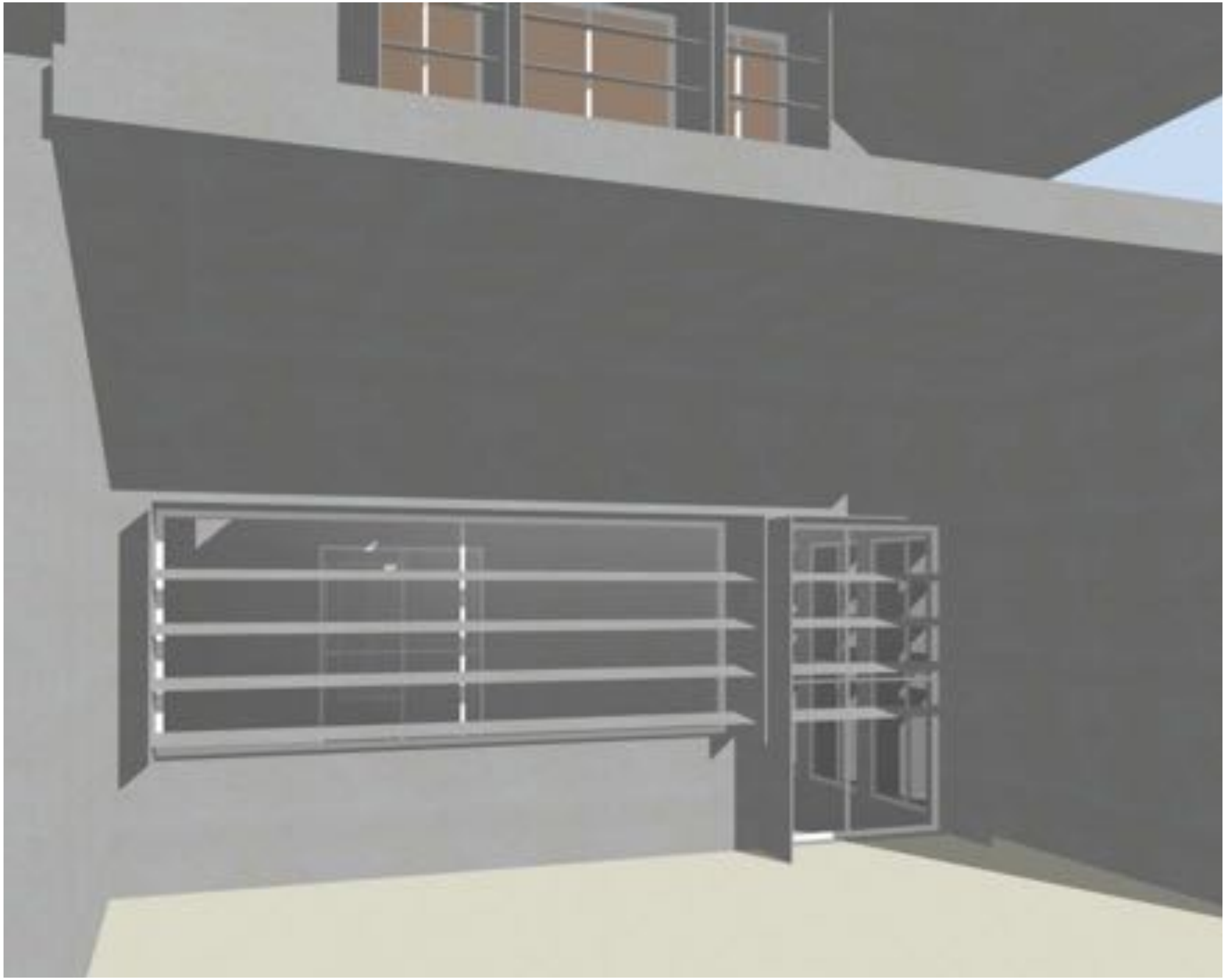
The Carbon Advisory Service Ltd.





Thermal modelling graphics, Illustration of window shading

The Carbon Advisory Service Ltd.



From the site survey it was apparent that almost every window was in shade from trees.

Rather than model every single villa with its adjacent trees, this effect has been simulated with window shades, as indicated here.

Thermal modelling, Building location plan

Integrated systems modelling

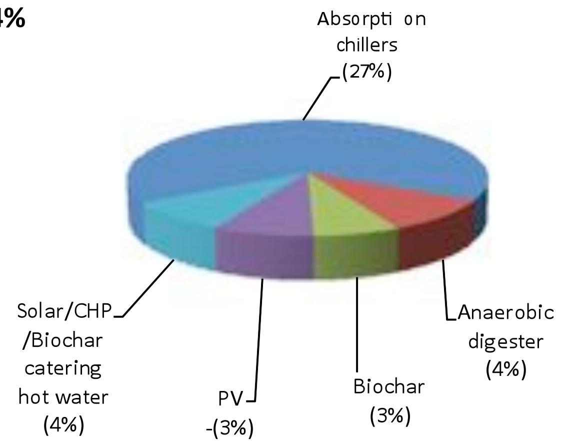
The Carbon Advisory Service Ltd.

This model has not been built for this staged update

Results
Carbon reduction strategies

The Carbon Advisory Service Ltd.

Technology	Emissions		Comment
Diesel generators	3475 t.CO2		4,355 MWh elect; 1,203,000 litres diesel
Absorption chillers	-929 t.CO2	(27%)	2,902 MWh cooling; 1,161 MWh elect; 1,451 MWh heat off generators
Anaerobic digester	-137 t.CO2	(4%)	470 kWh elect
Biochar	-100 t.CO2	(3%)	
PV	117 t.CO2	-(3%)	151 MWh elect. CO_2 saving considers deforestation. New PV should use roofs
Solar or CHP catering hot water	-125 t.CO2	(4%)	Estimated 156 MWh electricity
Balance	**2300 t.CO2**		
Saving	**1175 t.CO2**	**34%**	



For a site with no heating demand and most domestic hot water heated using waste heat from the electrical generators, the cooling would usually be a larger portion of the total CO_2 emissions.

Either the cooling demand is higher than currently modelled or there are significant opportunities to save electricity. Either of these scenarios will allow the CO_2 emissions to be reduced considerably more than shown here.

The cooling loads are still preliminary and as yet, no sensitivity analysis has been done. More work will be undertaken before October 2009 to establish these figures. However the cooling loads cannot be more than about 30% higher than indicated before the peak capacity of the scheduled fan-coils is reached. Increasing cooling emissions by 30% would still leave a large unexplained electrical load.

The next slide looks at an electrical load breakdown.

Results
Preliminary electrical load assessment

The Carbon Advisory Service Ltd.

Technology		Emissions	Comment
Cooling		929 t.CO2	To be confirmed
Lighting			
office	*52 t.CO2*		15 W/m² and 50% diversity, 65 MWh
Host flats	*198 t.CO2*		W/m² and 50% diversity, 248 MWh
Guest villas	*106 t.CO2*		5 W/m² and 35% diversity, 132 MWh
Retail	*4 t.CO2*		20 W/m² and 50% diversity, 5 MWh
Other	*72 t.CO2*		Allow 20% of the above
Total lighting		432 t.CO2	
Reverse Osmosis		298 t.CO2	373 MWh
Catering DHW		125 t.CO2	say 1500 covers per day, 7 litres DHW per cover, = 156 MWh
TOTAL		**1784 t.CO2**	**51%**

This table shows that cooling, lighting, water treatment and catering hot water is only about half the site's total electricity demand – this should not be so. Typically these loads would represent about 70%.

More work will be done before October 2009 to understand the balance. It could be that the cooling loads have been under-estimated by 20% or so, but even this would not explain the discrepancy. It is more likely that the demand can be reduced.