LABS FOR THE 21ST CENTURY

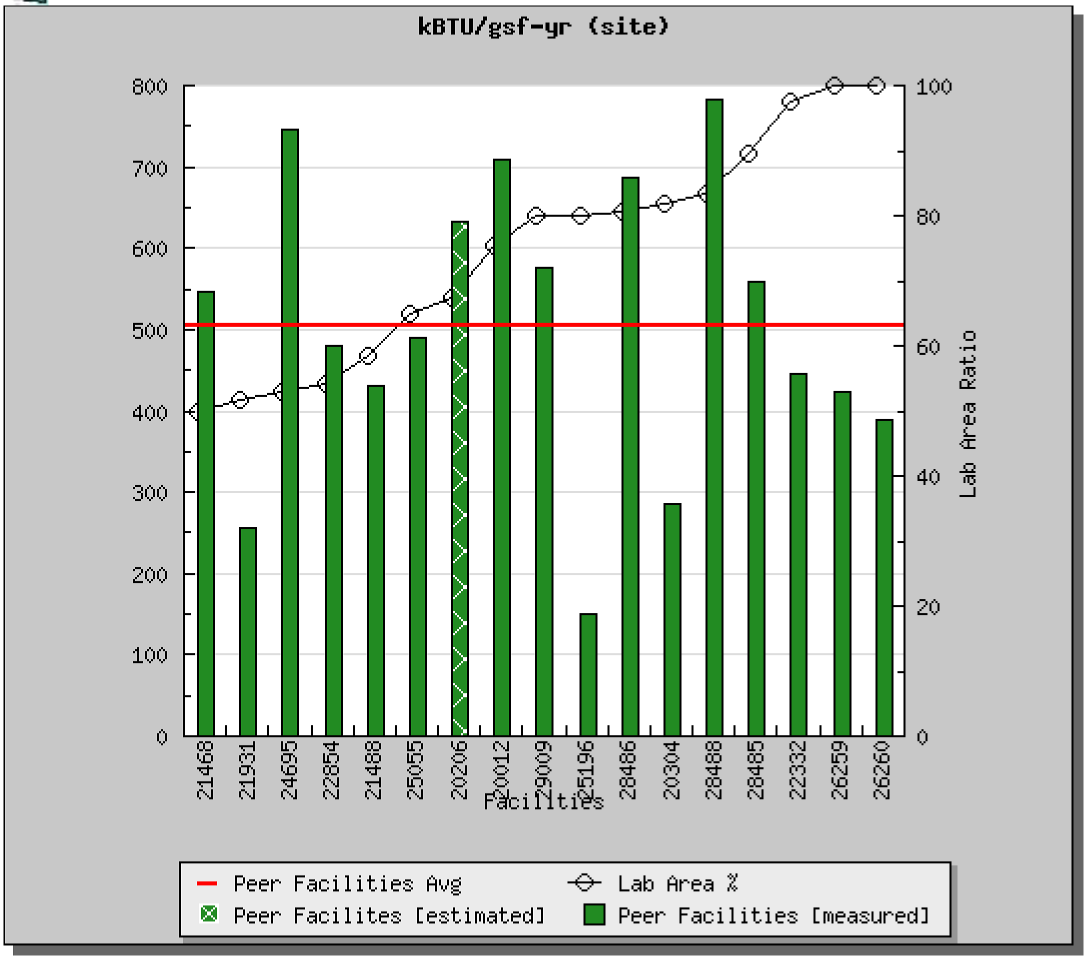
benchmarking

Benchmarking Results

How to read these results

User not logged in. (Log in)

Total Building kBTU/gsf-yr (site)



Lab area ratio: 0.5-1 | Occupancy hours: High
Lab type: Biological, ChemicalBiological
Lab uses: Research/Development
Climate Zones: 4A, 5A
Measured data: Yes   Estimated data: Yes

Benchmark Statistics for Peer Facilities				
Metric	Min	Avg	Max	Count
Total Building kBTU/gsf-yr (site)	150.35	505.15	782.9	17

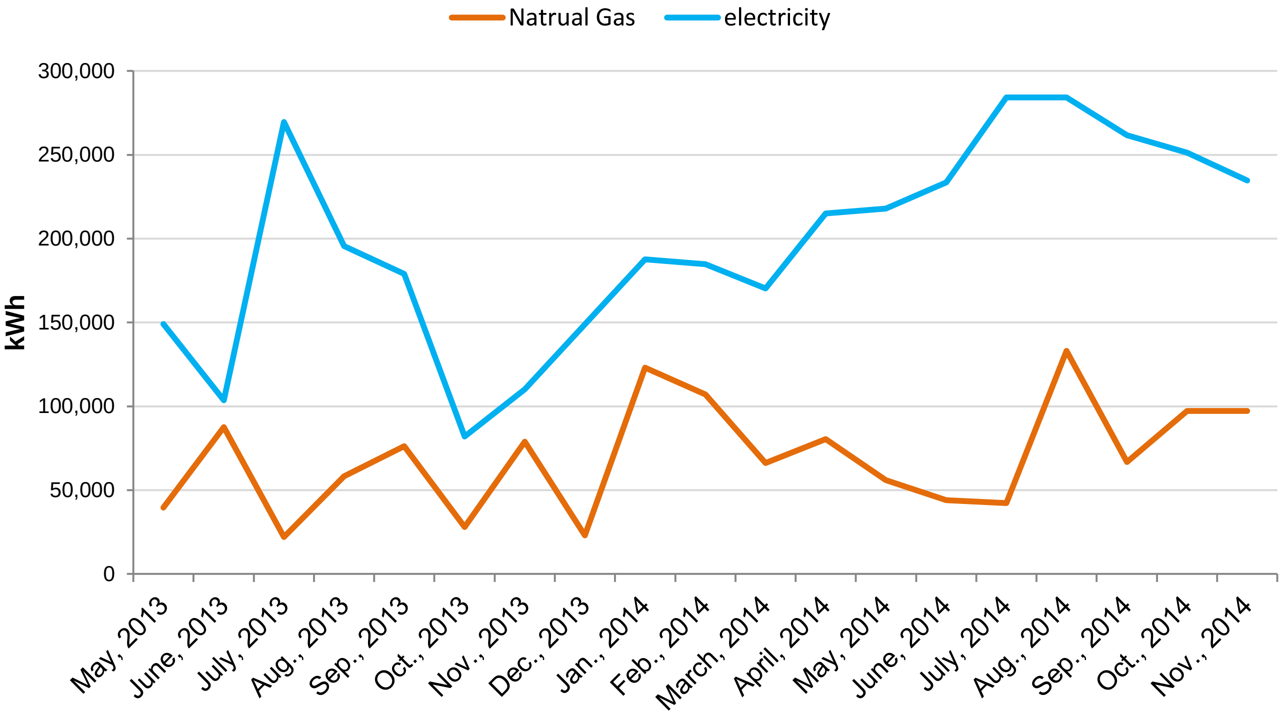
Click titles of columns below to sort
Data for your facilities are highlighted | Estimated data are indicated in *italics*

Facility	Lab Type	Year	kBTU/gsf-yr (site)	Lab Area Ratio	Occupancy hours per week	Climate
21468	ChemicalBiological	2009	547.35	50%	92	5A
21931	ChemicalBiological	2009	255.53	52%	168	4A
24695	ChemicalBiological	2010	746.74	53%	168	5A
22854	ChemicalBiological	2009	480.6	54%	90	4A
21488	ChemicalBiological	2010	429.59	58%	92	5A
25055	Biological	2011	489.46	65%	96	4A
20206	*Biological*	*2007*	*632.73*	*67%*	*108*	*5A*
20012	Biological	2001	708.61	75%	144	5A
29009	Biological	2014	575.22	80%	168	5A
25196	Biological	2011	150.35	80%	168	4A
28486	ChemicalBiological	2012	685.6	81%	168	4A
20304	Biological	2008	285.78	82%	100	5A
28488	ChemicalBiological	2012	782.9	83%	168	4A
28485	ChemicalBiological	2012	558.2	90%	168	4A
22332	Biological	2010	445.48	97%	168	4A
26259	ChemicalBiological	2012	423.37	100%	168	4A
26260	ChemicalBiological	2012	390.12	100%	168	4A

Change Metrics

Version 1.4

Operational Energy Data for Bioscience Research Building NUI Galway



Month	Natural Gas (kWh)	Electricity (kWh)
May, 2013	39,470	148,989
June, 2013	87,580	103,546
July, 2013	22,000	269,645
Aug., 2013	58,200	195,585
Sep., 2013	76,231	179,015
Oct., 2013	28,000	81,997
Nov., 2013	78,800	110,166
Dec., 2013	23,000	148,867
Jan., 2014	123,140	187,569
Feb., 2014	107,000	184,802
March, 2014	66,100	170,268
April, 2014	80,400	215,037
May, 2014	56,000	217,992
June, 2014	44,000	233,492
July, 2014	42,300	284,280
Aug., 2014	133,000	284,280
Sep., 2014	66,760	261,631
Oct., 2014	97,247	251,280
Nov., 2014	97,247	234,640

EUI Dec., 2013-Nov. 2014 451.3 kWh/m^2

NUI GALWAY

ENERGY OPTIONS REPORT

Ref : 8061/PJH/JW

Issue No. 02

REVISION STATUS

Issue	Date	Notes	Prepared By	Checked By
01	March 2008	Options Report	PJH/JW	JW
02	March 2008	Carbon emissions updated to those set out in ROI Domestic energy assessment spreadsheet.	JW	JW

CONTENTS

1. EXECUTIVE SUMMARY

This energy options report describes the energy efficiency measures, on site generation and embedded renewable energy strategies that could be adopted to substantially reduce the energy demands and carbon emissions, arising from fossil fuel use, from the proposed new buildings at NUI Galway.

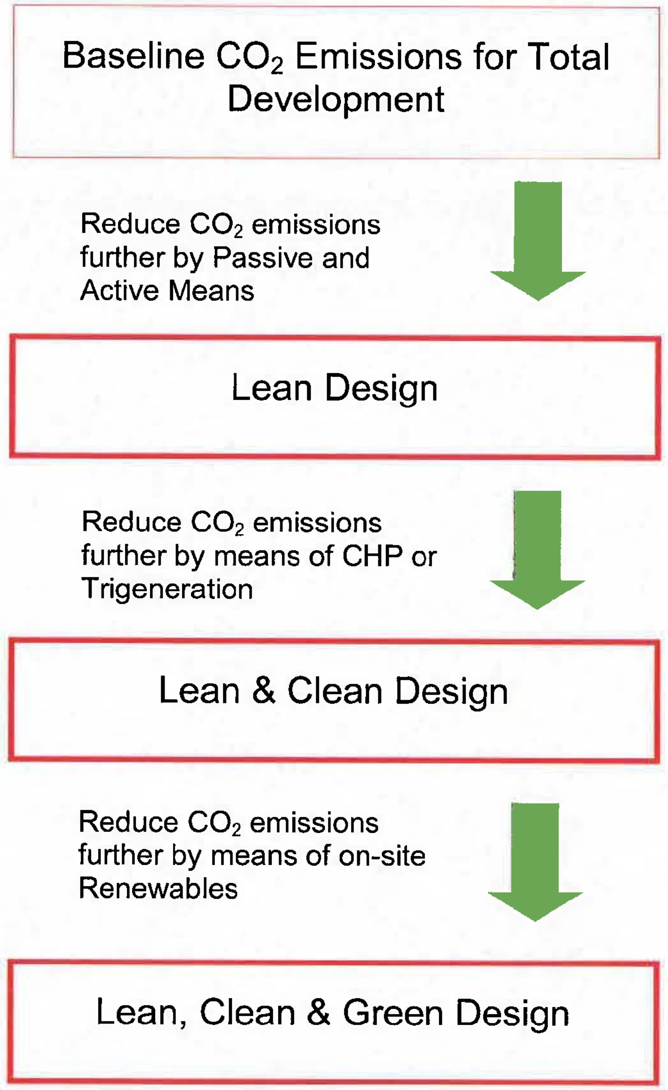
The Stage 1 Report addressed the fundamental building services requirements for the four buildings that form the project. Reference was made to further studies that would consider sustainable solutions. The Energy Options review takes the form of a review of the various energy saving options and technologies based upon generic and indicative information, and is designed to identify those options to be incorporated into the designs

Clean and *Green* Options have been considered on the following basis :-

- Option Description
- Capital Cost
- Payback Period
- Energy Savings
- Reduction in Carbon Emissions
- Impact Upon the Building
- Impact Upon the Site

Lean Options are generally considered to be good practice that is integral to the general building design with the capital costs often less readily abstracted.

This Energy Options Report follows a “lean, clean & green” approach as illustrated in the adjacent diagram. An assessment for the predicted energy consumption and resultant CO_2 emissions has been made based upon published benchmark data (See Appendix 1). The impact of reducing the energy demands ‘lean’, supplying energy efficiently ‘clean’ and use of renewable energy ‘green’ has then been assessed to establish the most appropriate energy strategy for the development.



The measures that have been considered to reduce CO_2 emissions are described below, and those recommended for adoption are indicated with a tick. Some Option are possible and may be considered worthy of further discussion and consideration and they are marked with a question mark:

PASSIVE & ACTIVE ENERGY EFFICIENCY MEASURES

Option	SRB	CRF & TRF	Library
Optimised glazing design to improve day-lighting, reduce overheating and provide useful winter solar heating	✓	✓	✓
Low energy white goods	✓	✓	✓
Variable flow air & water systems	✓	✓	✓
Low energy lighting and lighting control	✓	✓	✓
Improved chiller efficiency	✓	✓	✓
Air heat recovery to ventilation systems	✓	✓	✓
EC/DC motor fan coil units	✓	✓	✓
Power factor correction	✓	✓	✓

COMBINED ELECTRICAL AND THERMAL ENERGY SUPPLY SYSTEMS

Option	SRB	CRF & TRF	Library
CCHP	✗	✗	✗
Central CHP	✗	✗	✗
Gas Fired CHP	✓	✗	✓
Biomass CHP	?	✗	?
Heat driven Desiccant Cooling	✗	✗	✓

RENEWABLE ENERGY

Option	SRB	CRF & TRF	Library
Photovoltaic Cells	✗	✗	✗
Solar Hot Water Heating	✗	✓	✗
Small Wind Turbines at each building	✗	✗	✗
One Larger Central Wind Turbine	?		

2. INTRODUCTION

2.1 PURPOSE AND CONTENT OF THIS REPORT

Reducing carbon dioxide emissions into the atmosphere to reduce impact on climate change is one of the major objectives of sustainable development. This report considers a number of measures by which this can be achieved for the Biosciences development at NUI Galway and recommends those which are most appropriate in terms of environmental, technical and economic feasibility. It demonstrates that developments such as this can provide modern buildings in which people can work comfortably without the need to consume large amounts of fossil fuel and the release of unsustainable quantities of carbon dioxide into the atmosphere

This is a technical report. It assesses a baseline energy profile for each of the buildings in summer, winter, and spring/autumn, and then considers passive and active measures to reduce energy consumption followed by the options for on site generaton of electrical power and heat and finally it considers the use of renewable energy technologies.

The option assessments are made early in the design process prior to the availability of a computer generated energy computer model of the building. Undertaking an early assessment has the benefit of allowing the selected technologies to be incorporated into a particularly fast design programme.

The report starts with such a *Baseline* building that complies with UK "good practice" as recommended for use with new buildings. Energy conservation opportunities are assessed against this.

The adoption of both passive and active design features then leads to a *"Lean"* building.

It is against this *"Lean"* energy demand that options for C/CHP option are assessed which leads to a *"Clean"* building.

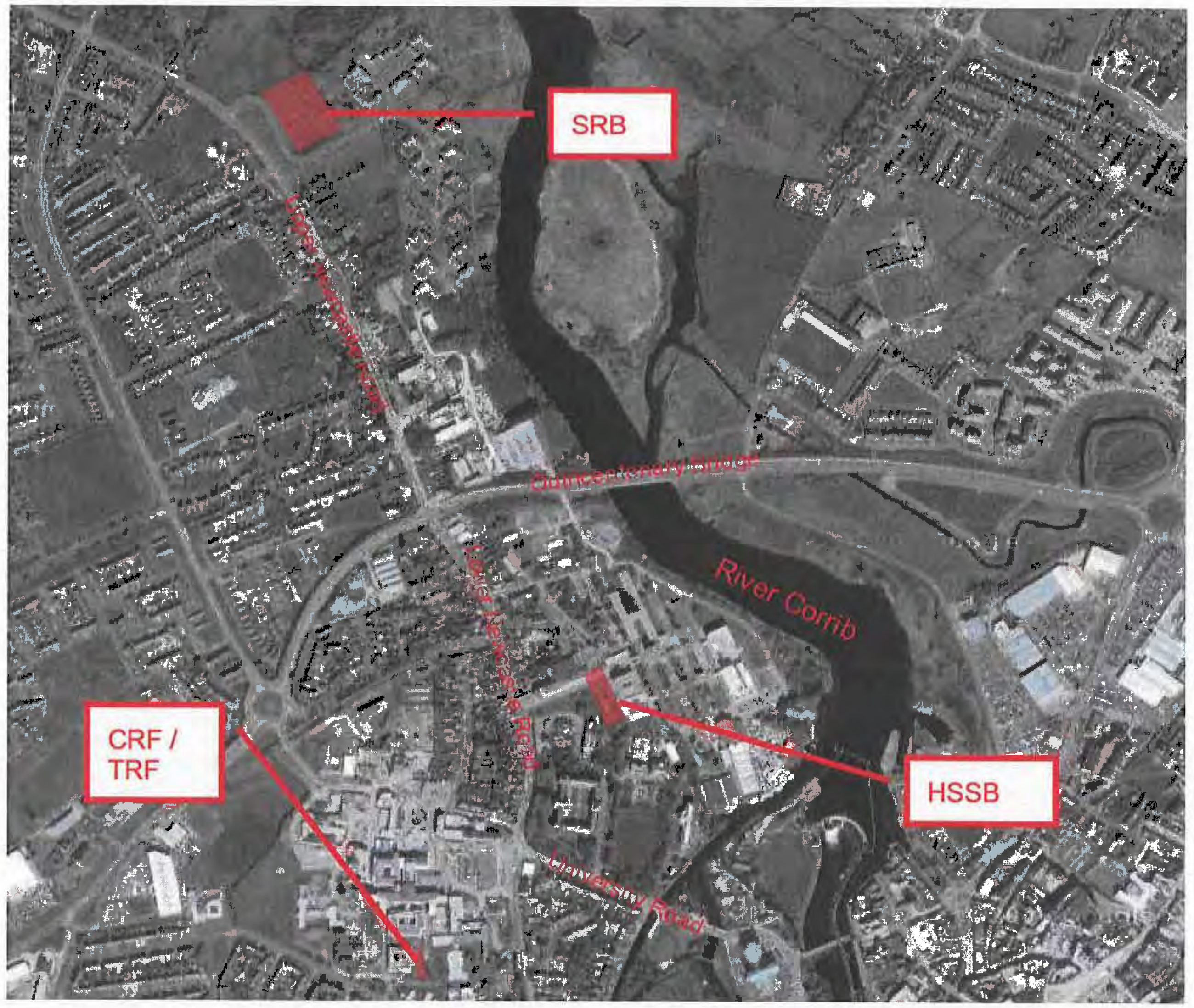
Finally, renewable *"Green"* technologies are assessed against the *"Lean & Clean"* building.

The renewable energy technologies considered are:

- Bio-fuel C/CHP combined cooling, heat and power
- Photovoltaics
- Solar Hot Water Heating
- Wind Turbines

2.2 BUILDING LOCATION ON SITE

The site plan below shows the location of the proposed buildings on the site. The new library extension is located toward the middle of the site, with the CRF, and TRF buildings around half a mile to the South and the SRB approaching a mile to the North.



2.3 CARBON EMISSIONS

2.3.1 Carbon Emission Values Including Gas and Electricity from the Grid

This report uses the carbon intensities as set out below. The values are based upon those used in assessing compliance with carbon emissions and compliance with the Building Regulations for England and Wales.

2.3.2 Electricity Generated on Site

It should be noted that the ROI domestic energy assessment spreadsheet sets the same carbon emission level for both grid supplied and grid displaced electricity.

The carbon emission level for grid supplied electrical power is considerably above the level of 0.422 $kgCO_2/kWh$ used in the UK presumably due to the absence of nuclear power in the ROI. The emission levels for grid displaced electrical energy in the UK is also taken to be higher than grid generated electrical power to take into account that the first power stations to be shut down or replaced will be the least efficient. Such an adjustment has not been declared in the ROI domestic energy spreadsheet.

2.3.3 Biomass/Fuel

A carbon intensity of 0.025$kgCO_2/kWh$ is taken for Biomass fuel.

Fuel	**Carbon Intensity** $kgCO_2/kWh$
Natural Gas	0.203
Biomass (Woodchip)	0.025
Electricity (Grid supplied)	0.643
Electricity (Grid displaced for site generation)	0.643

2.4 OPERATING COSTS

This report uses the energy costs as set out below. The values are based upon those advised by Noel O'Connor (Communications Reference 8061/0215/NDB) inclusive of VAT which is charged at 13.5%. For the purposes of this analysis, it is assumed that the day-time electrical tariff applys to the hours of 07:00 – 19:00 and the night-time electrical tariff would apply to the hours of 19:00 – 07:00.

Fuel	**Energy Costs cents/kWh**
Natural Gas	5.11
Biomass (Woodchip)	3.97
Electricity (Day)	13.85
Electricity (Night)	8.85

A weighted average electrical cost of 12 cents/kWh for all electrical consumption has been used in calculation of the cost of energy consumed.

2.5 ENERGY STRATEGY

The Energy Hierarchy follows good practice in the design of low carbon buildings, comprising three distinct stages and order of application:

- Use Less Energy (Be Lean)
- Supply Energy Efficiently (Be Clean)
- Use Renewable Energy (Be Green)

2.6 PART L BUILDING REGULATIONS IRELAND

Carbon emissions, attributable to buildings in use, result from lighting, heating, cooling, ventilation and small power, (business machines, domestic and laboratory appliances etc). The Building Regulations of Ireland 2005 (May 2006 Edition) (Part L) appears to generally follow the form and route taken by those applying to England and Wales but have yet to reach the point where they make specific requirements that limit carbon emissions.

The overriding requirement of the Building Regulations Part L is to ensure that buildings are designed and constructed such that when in use they do not consume excessive energy and power. Specific requirements of the current Building Regulations as applicable to new non domestic buildings in summary include :-

Maximum and maximum average permissible U values specified

Element	Maximum U value W/m²/K
Windows	2.2 based upon windows being 40% of exposed wall area
roofs	0.25
walls	0.37
Exposed floors	0.37
ground floors	0.37

The maximum average is a sliding scale that relates to the ratio of the treated floor area divided by the volume of the treated space.

Maximum permissible rate of infiltration not stated

Solar gain through windows not to exceed 25W/m^2 of floor area

ACMV should not be necessitated due to gains through the fabric

Heating plant to satisfy SI no 260 of 1994 European Communities.

Controls for Larger Complex buildings to follow CIBSE Guide H: Building Control Systems

Specific Fan powers for new buildings not to exceed 2.0 W/l/s

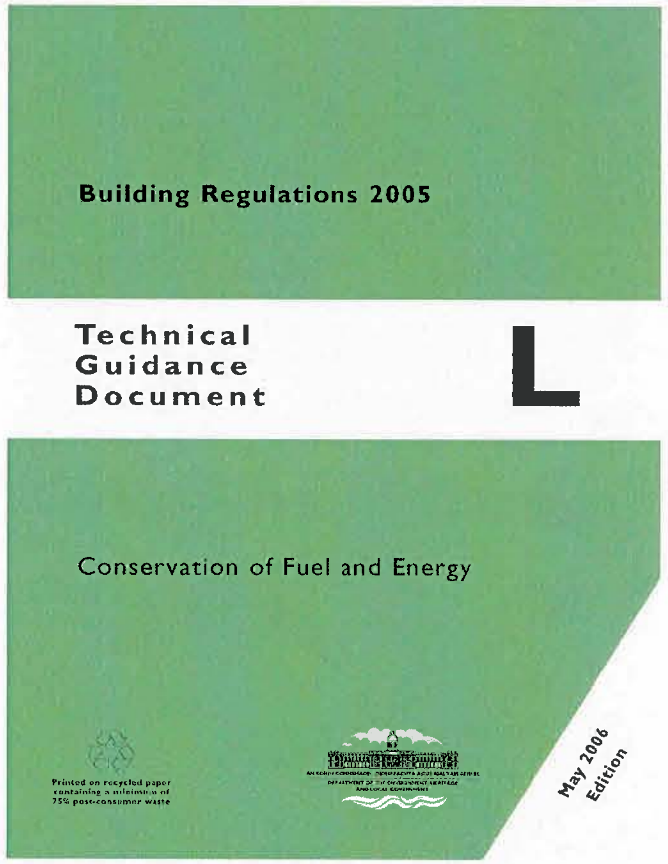
Part load efficiencies to be reasonably efficient following the guidance given in Action Energy General Information, Report 41 (GIR041) Variable flow general information published by BRECSU.

Pipework and ductwork to be insulated in accordance with British Standards.

Lighting – minimum lamp efficacies specified as not less than 65 lumens per circuit Watt.

Lighting control – various types of daylight control permitted

It should be noted that the energy and carbon emission figures in this report include allowances for small power, whereas they are excluded from the building regulations, since they relate to the process within the building and not to the building.



Building Regulations 2005

Technical Guidance Document

L

Conservation of Fuel and Energy

May 2006 Edition

3. BASELINE

The *Baseline* represents a development which is anticipated to just meet minimum standards of the Building Regulations. As no final models of the building yet exist, typical values for new "good practice buildings have been used.

The results of these calculations are summarised in the table below:

Building	Treated Area	Annual Energy Consumption (kWh/m^2/Year)			Annual Operating Costs (€/m^2 /Year)			Annual Carbon Emissions (kg/m^2/Year)		
		Electricity	Fossil Thermal	Total	Electricity	Fossil Thermal	Total	Electricity	Fossil Thermal	Total
SRB	6,639	285	428	713	34.2	21.9	56.1	183	87	270
CRF&TRF	3,290	231	347	578	28	18	46	149	70	219
HSSB	4,858	428	271	699	51	13.8	64.5	275	75	330

The total CO_2 emissions for the new biosciences development at NUI Galway is predicted to be 4115 tonnes per year.

4. LEAN - ENERGY EFFICIENCY MEASURES

4.1 PASSIVE DESIGN FEATURES

4.1.1 Improved Building Envelope Performance

The project will adopt the following criteria for the thermal performance :-

Element	U – value W/m^{2}C
Walls & opaque elements	0.202
External Roof	0.165
Ground bearing slabs/slabs over unheated area	0.187
External Glazing (U Value)	1.8
External Glazing (G value)	0.35

The above values represent a 25% improvement on the requirements of the Building Regulations.

Cladding systems will have air leakage rates not exceeding 0.5m^3/hr/m^2 (referenced to 100Pa) and tested to 600Pa. The overall leakage rate under Part L leakage test 3.0m^3/hr/m^2.

The design of the fenestration has a significant impact on the energy demand of a building in terms of heating, cooling and artificial lighting. Too little glazing, or poor daylight transmittance of the glazing system, will reduce the demand for heating and cooling energy but will reduce daylight levels within the perimeter areas and so increase the energy consumption by artificial lighting. Too much glazing, or glazing of poor thermal and solar performance, will reduce energy demand for artificial lighting but increase demand for heating and cooling. Furthermore, the benefit of increased daylight falls off rapidly once daylight factors exceed about 5%.

The fenestration also has a major impact on views out which is known to affect the well being of occupants. This aspect needs to be considered when selecting an optimum type and area of glazing.

Advice has been provided to the project team regarding fenestration on each of the elevations. A key objective of the guidance provided was to reduce solar heat gains through windows around the perimeter of the building to a value not exceeding 25W/m^2 of floor area. At this level of solar heat gain the internal spaces should sustain a good level of thermal comfort in warmer periods without the need for air conditioning, or comfort cooling. Mechanical ventilation is only provided where the process undertaken within the building requires either control of air flow, or pressures or because the heat emissions from process within the building necessitates cooling.

4.1.2 Thermal Mass

High thermal mass improves the ability of the building structure to reduce the incidence of overheating through day and maximises the effectiveness of night-time ventilation.

Advise has been provided on the form of window openings and on the benefit of being able to open fanlight windows overnight in periods of warm weather to cool the exposed soffit of concrete floor slabs overnight. This technique has been shown to reduce room temperatures during the day by around 2°C.

Automatically controlled fanlight windows are usually used to achieve night time free cooling.

4.2 ACTIVE DESIGN FEATURES

4.2.1 Low Energy White Goods

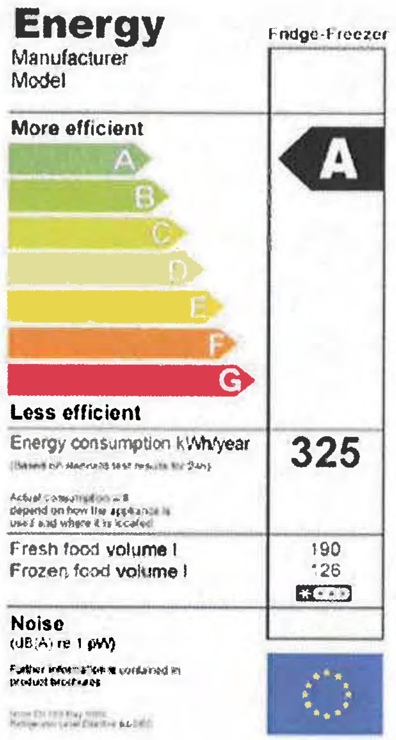
White goods include fridge/freezers, microwave ovens, and dishwashers,

These items are responsible for around half of electrical consumption in dwellings. In laboratories and libraries they will account for a much lower proportion of energy consumption, White goods are now provided with a certified energy label. These are rated A+, A, B and C with C being the least efficient. Data supplied by the Energy Advice Centre suggests that using A rather than C rated white goods would reduce electrical energy consumption in each dwelling by 800 kWh/year.

We are not aware of any specific data relating to energy emissions from white goods within laboratories and libraries.

It is recommended that all white goods provided will be rated at the highest energy rating available, and at this stage we have made the following allowances for the use of A rated white goods

Building	White Goods Energy Savings Allowance kWh/m^2/yr
HSSB	800
CRF & TRF	2000
SRB	2000



4.2.2 Variable Flow Air & Water Systems

Variable flow ventilation will be used in laboratories both on fume cupboard, and general extract and also on the associated supply air systems

All cooling and heating water systems will, where appropriate, utilise variable flow pumping to minimise power consumption by pumps.

As the system designs are progressed the savings from variable flow air and water systems will be analysed in more detail. Significant savings can be expected.

4.2.3 Low Energy Lighting and Lighting Control

“Low energy lamps”, (compact fluorescent or linear fluorescent) use about 80% less energy than conventional tungsten lamps for the same light output.

Even greater savings are claimed for the latest LED lamps which are becoming available for luminaries. The use of such lamps should be investigated further as detailed design progresses.

Presence detection is proposed to control lighting within internal and perimeter areas throughout all of the buildings with the possible exception of areas where it would be unsafe to do so.

Photo cells are proposed to progressively dim lighting in perimeter areas up to a depth of 5 metres from perimeter walls that contain windows.

4.2.4 High Efficiency Chillers

Mechanical cooling will be minimised through the passive and active design, and other means referred to elsewhere in the report

The England and Wales building regulations require a minimum full load EER for air cooled chillers of 2.25. Where cooling is provided by vapour compression air cooled chillers it is intended that they will be selected to have a full load EER of at least 4.5.

4.2.5 Heat Recovery

Heat recovery is now commonly used on ventilation systems to recover heat from the exhaust air to preheat the incoming fresh air.

The three most commonly used types of system are :-

Heat Recovery System	Features & Characteristics
Run around coils	The easiest system to use – supply and extract ductwork do not need to be brought together. No possibility of the exhaust air contaminating the supply air No ability for moisture transfer Typically 50% heat recovery efficiency
Recuperators	Supply and extract ductwork need to be brought together – resulting in large air handling plant Possible contamination of the supply air by the exhaust air if there is leakage between the two ducts No ability for moisture transfer Typically 60% heat recovery efficiency
Thermal Wheel	Supply and extract ductwork need to be brought together – resulting in large air handling plant Possible contamination of the supply air by the exhaust air . Not well suited where the exhaust air could be contaminated with odours. Ability for moisture transfer Typically 80% heat recovery efficiency, but can approach 90%.

The following application of ventilation heat recovery systems is proposed :-

Building	Heat Recovery System
HSSB	Thermal wheels for main reading areas as part of a system that uses desiccant cooling. Recuperator – Fresh air ventilation to podium level
CRF & TRF	Laboratory ventilation systems - Run around coils
SRB	Laboratory ventilation systems - Run around coils

4.2.6 DC Motors for Fan Coil Units

Historically fan coil unit motors have been very inefficient. Recent advances in fan motor technology have resulted in substantial reductions in energy consumption, for an otherwise significant proportion of building energy use.

EC/DC (electronically commutated direct current) motors are proposed in place of conventional AC motors.

Fan coil units are used in the following applications

Building	Application of fan coil units
HSSB	Small rooms with high equipment heat gains, and room where the loads exceed those that can be dealt with using displacement ventilation alone.
CRF & TRF	Small rooms with high equipment heat gains
SRB	Small rooms with high equipment heat gains

4.2.7 Power Factor Correction

Power factor correction to the building electrical supply can provide significant savings in electrical consumption.

A minimum power factor of 0.95 could result in the CO_2 emissions reductions shown below.

5. *"LEAN"* BUILDING DESIGN

5.1 *"LEAN"* BUILDING SAVINGS

The table below summarises the anticipated benefits of adopting the 'Lean' building design features.

Technology	**HSSB**			**CRF & TRF**			**SRB**		
	Energy Cost Savings (€ / Year)	CO_2 Emissions Savings (Tonnes/Year)	% CO_2 Savings (of Baseline Building)	Energy Cost Savings (€ / Year)	CO_2 Emissions Savings (Tonnes/Year)	% CO_2 Savings (of Baseline Building)	Energy Cost Savings (€ / Year)	CO_2 Emissions Savings (Tonnes/Year)	% CO_2 Savings (of Baseline Building)
Fenestration and Thermal Mass	34,645	176.9	11.0%	29,313	150	20.8%	78,298	403	22.5%
Low Energy White Goods	96	0.5	0.0%	240	1.3	0.2%	240	1.3	0.1%
Variable Flow Air & Water Systems	15,594	83.6	5.2%	6,423	34.4	4.8%	15,983	85.6	4.8%
Low Energy Lighting and Lighting Control	7,358	39.4	2.5%	4,941	26.5	3.7%	12,614	67.6	3.8%
High Efficiency Chillers	45,356	243	15.2%	16,442	88.1	12.2%	29,408	157.6	8.8%
Heat Recovery	30,702	122	7.6%	10,5010	41.9	5.8%	39,527	157.1	8.8%
DC Motors for Fan Coil Units	2,154	11.5	0.7%	298	1.6	0.2%	455	2.4	0.1%
Power Factor Correction	27,388	146.8	9.2%	16,629	89.1	12.4%	20,602	110.4	6.2%
Total Lean Design Savings	€163,293	824	51%	€59770	433	60%	€118907	985	55%

The overall lean building design savings for the project are estimated to be:-

A Carbon Dioxide emission saving of 2,242 Tonnes/Year, which represents a saving of 54% of the Baseline buildings emssions.

An annual energy cost saving of €341,970 / year.

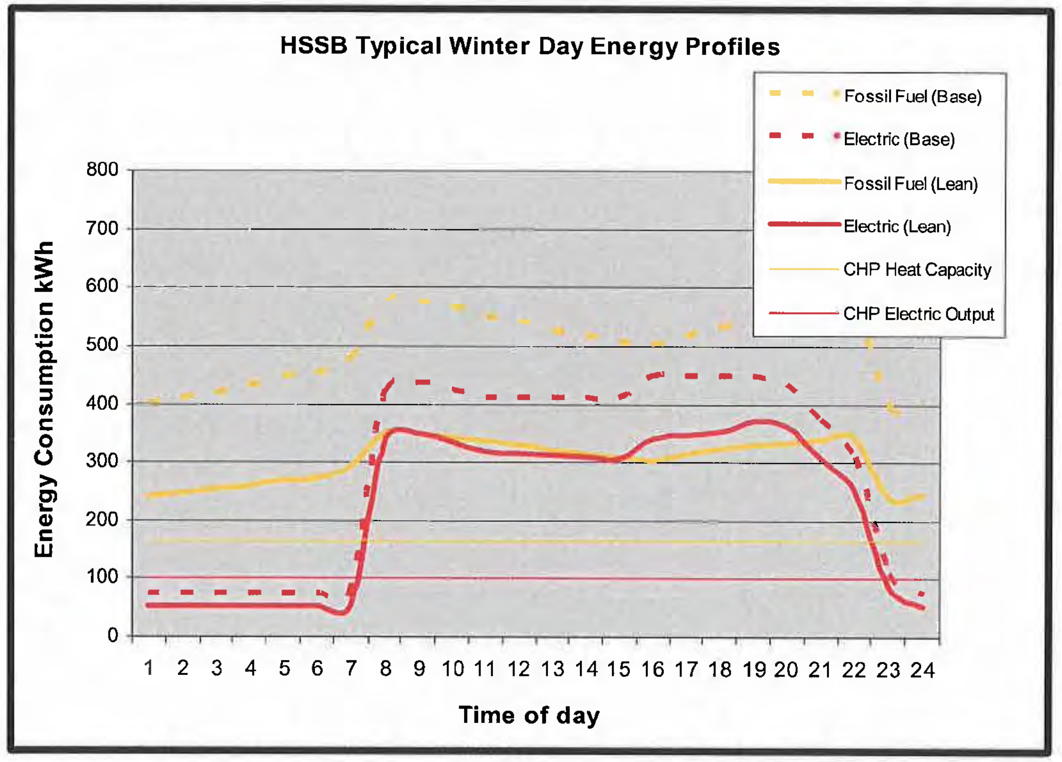
5.2 *"LEAN"* BUILDING ENERGY PROFILES

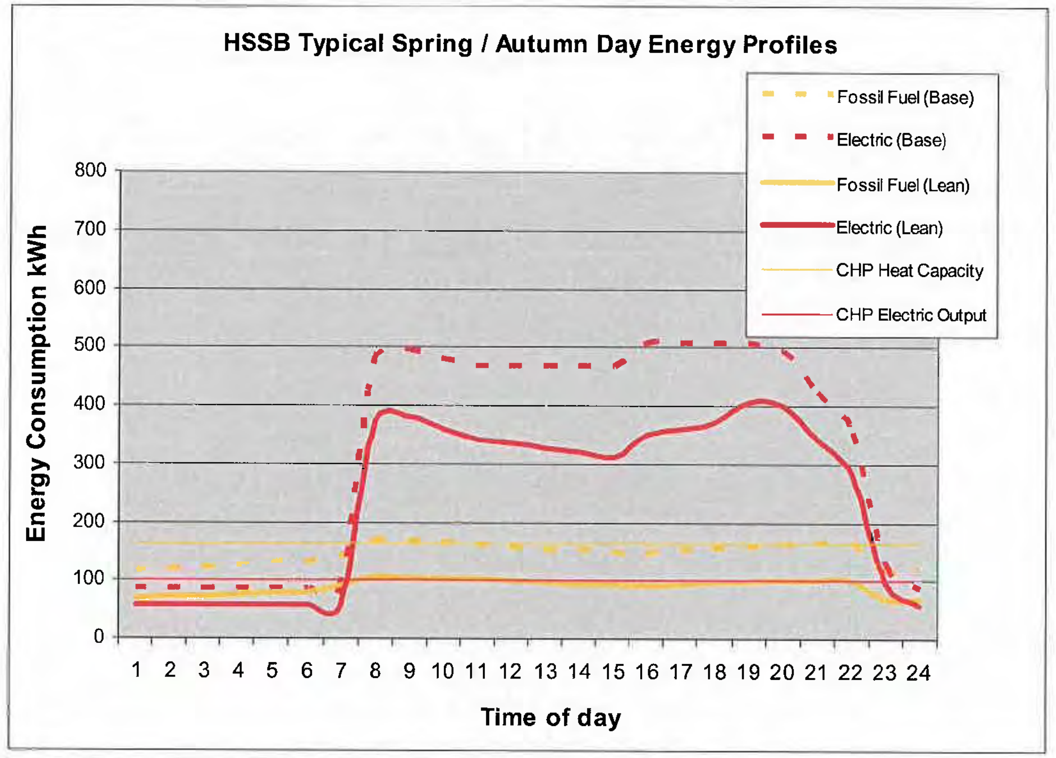
5.2.1 HSSB

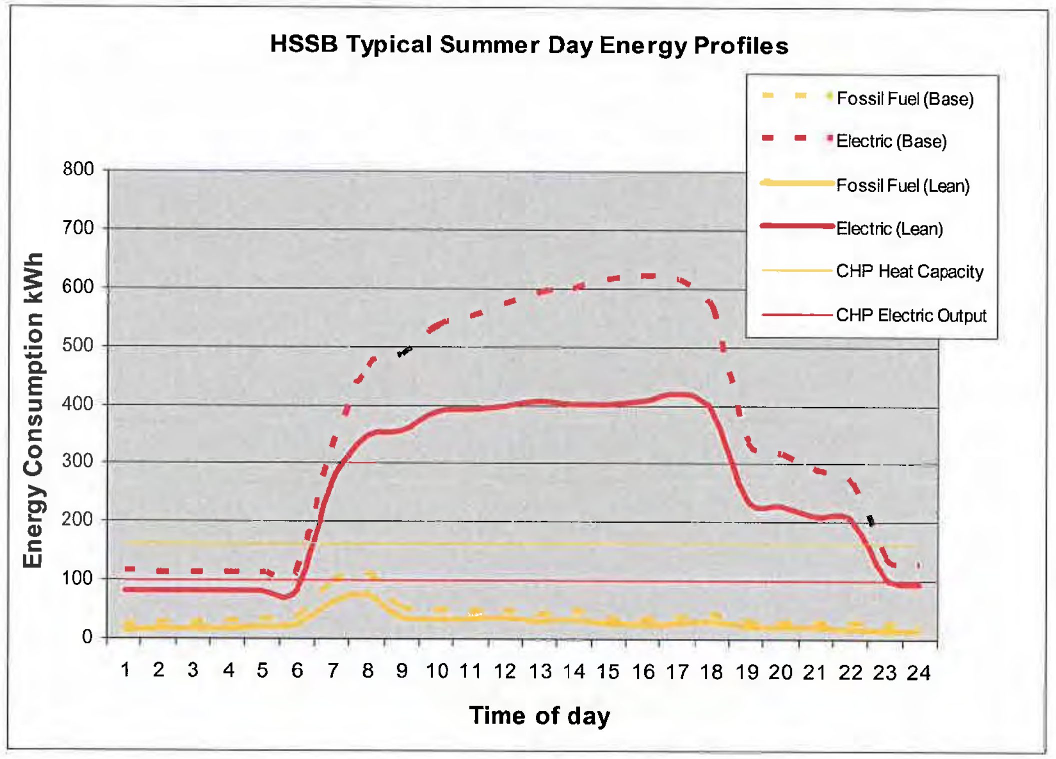
Indicative energy consumption profiles have been produced for building operation on typical days during the heating season (winter), mid-season conditions (spring / autumn) and cooling season (summer). The Energy profiles demonstrate how the proposed 'Lean' design measures will reduce the anticipated fossil fuel and electricity demands on an hourly basis.

It must be remembered, however, that the profiles are based upon typical days in each season, the peak loads will be much higher. It should also be noted that the heating profiles include heating for domestic hot water as the demand occurs. The proposed scheme incorporates hot water storage, which will in effect reduce the peaks and create a more even demand.

These demand profiles suggest that it may be appropriate to consider combined heat and power systems capable of providing 100kW$_e$ and 165kW$_{th}$ for the HSSB.





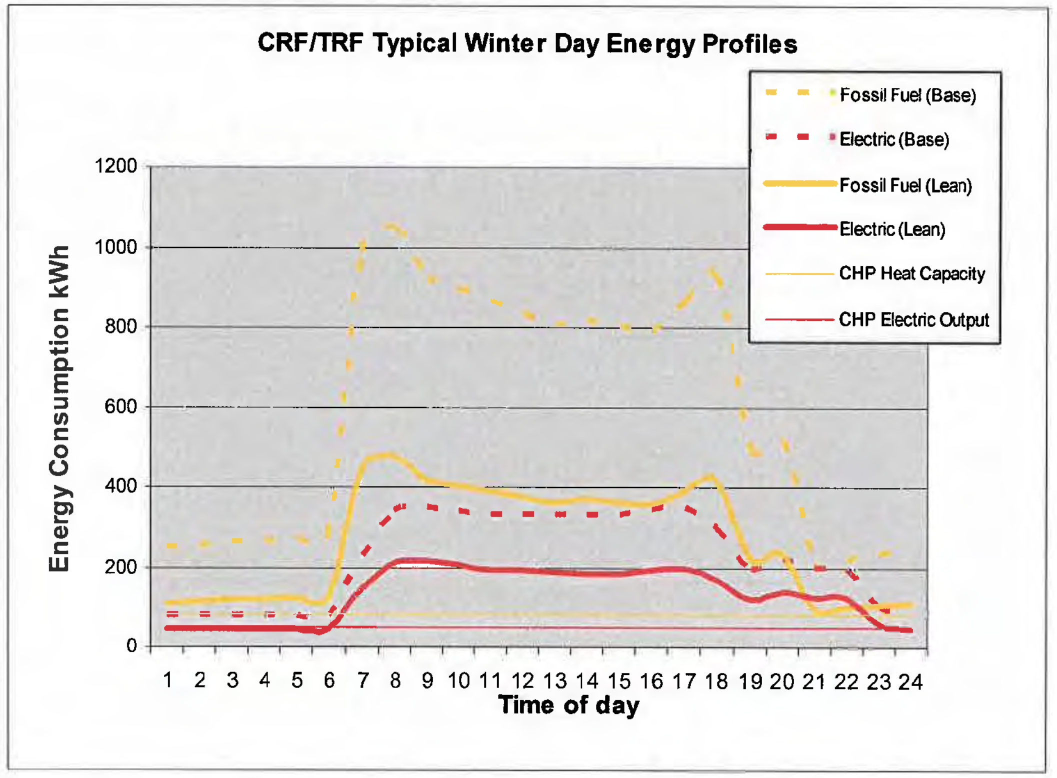


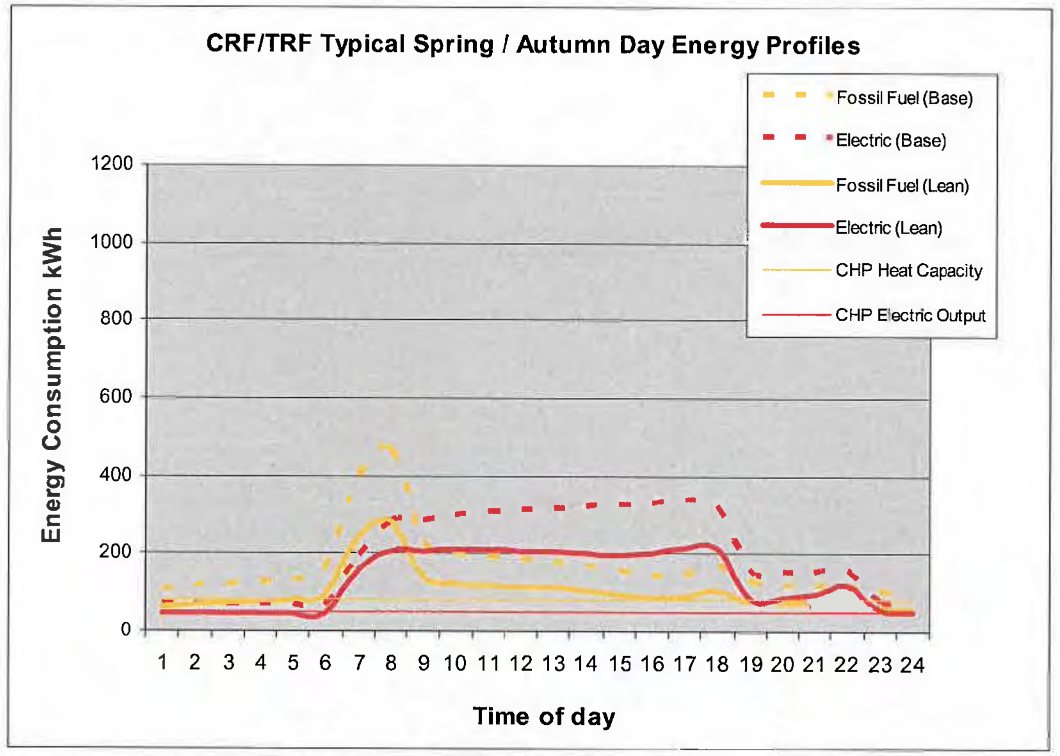
5.2.2 CRF / TRF

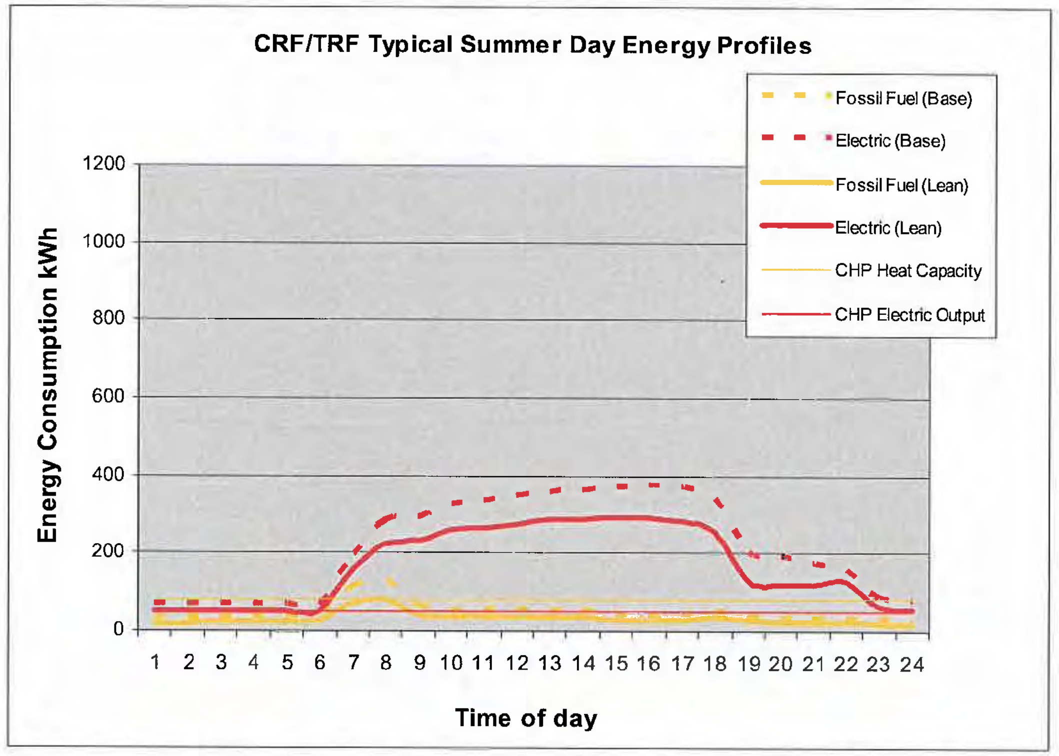
Indicative energy consumption profiles have been produced for building operation on typical days during the heating season (winter), mid-season conditions (spring / autumn) and cooling season (summer). The Energy profiles demonstrate how the proposed 'Lean' design measures will reduce the anticipated fossil fuel and electricity demands on an hourly basis.

It must be remembered, however, that the profiles are based upon typical days in each season, the peak loads will be much higher. It should also be noted that the heating profiles include heating for domestic hot water as the demand occurs. The proposed scheme incorporates hot water storage, which will in effect reduce the peaks and create a more even demand.

These demand profiles suggest that it may be appropriate to consider combined heat and power systems capable of providing 50kW$_e$ and 80kW$_{th}$ for the CRF / TRF.





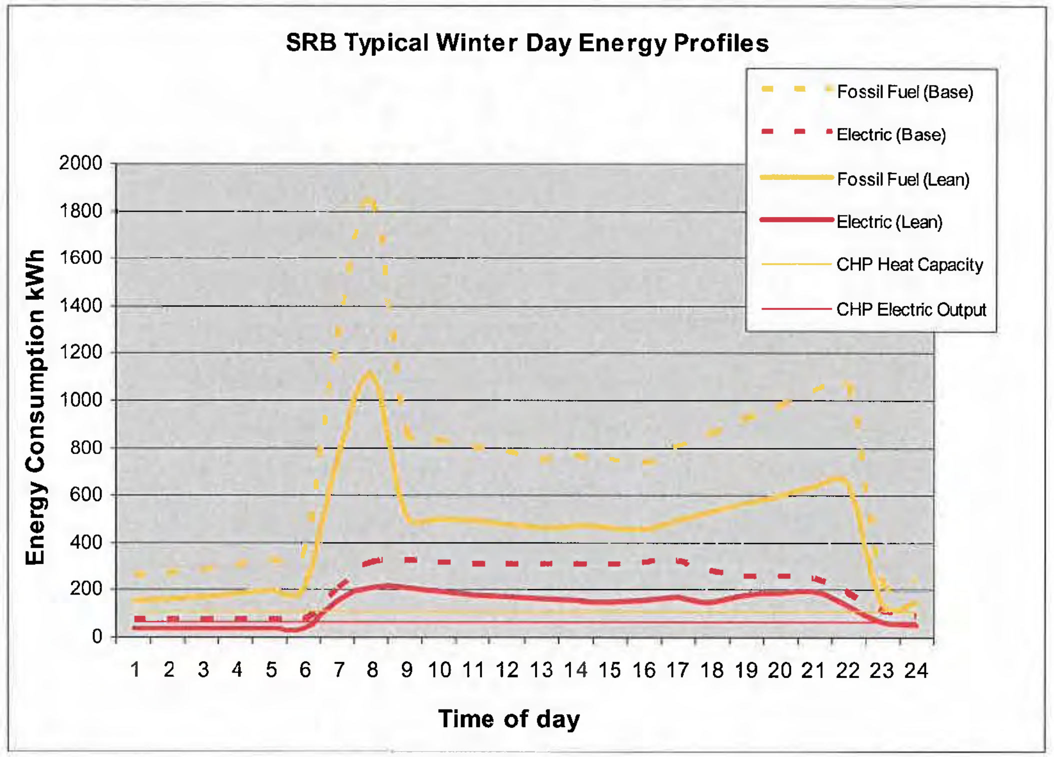


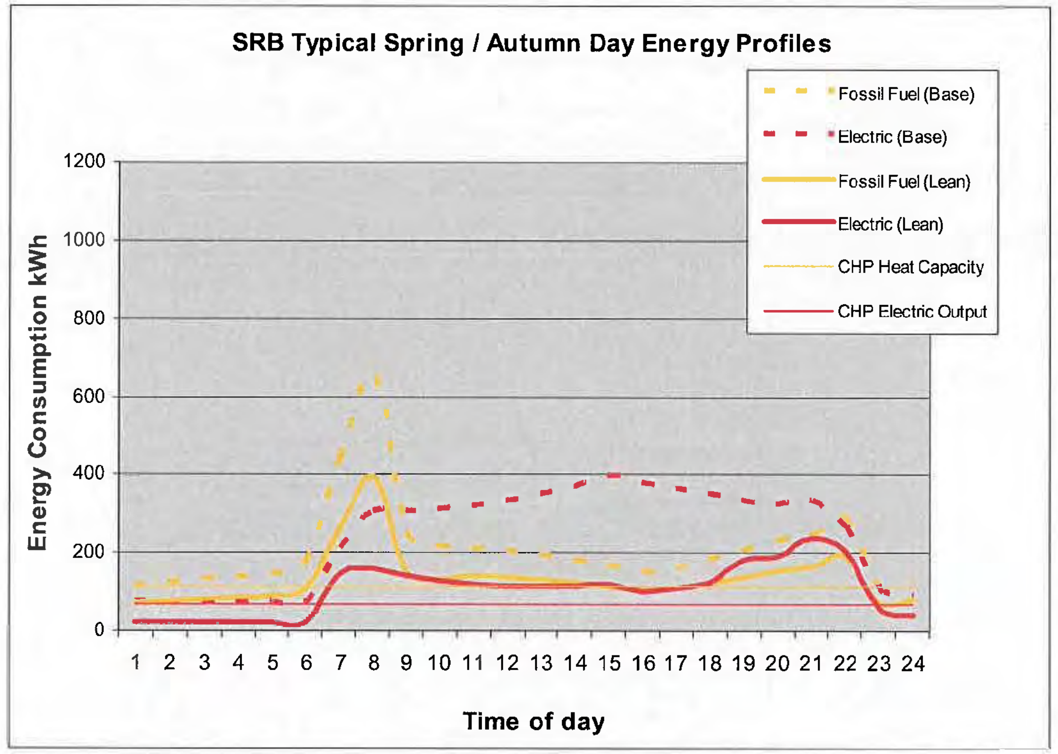
5.2.3 SRB

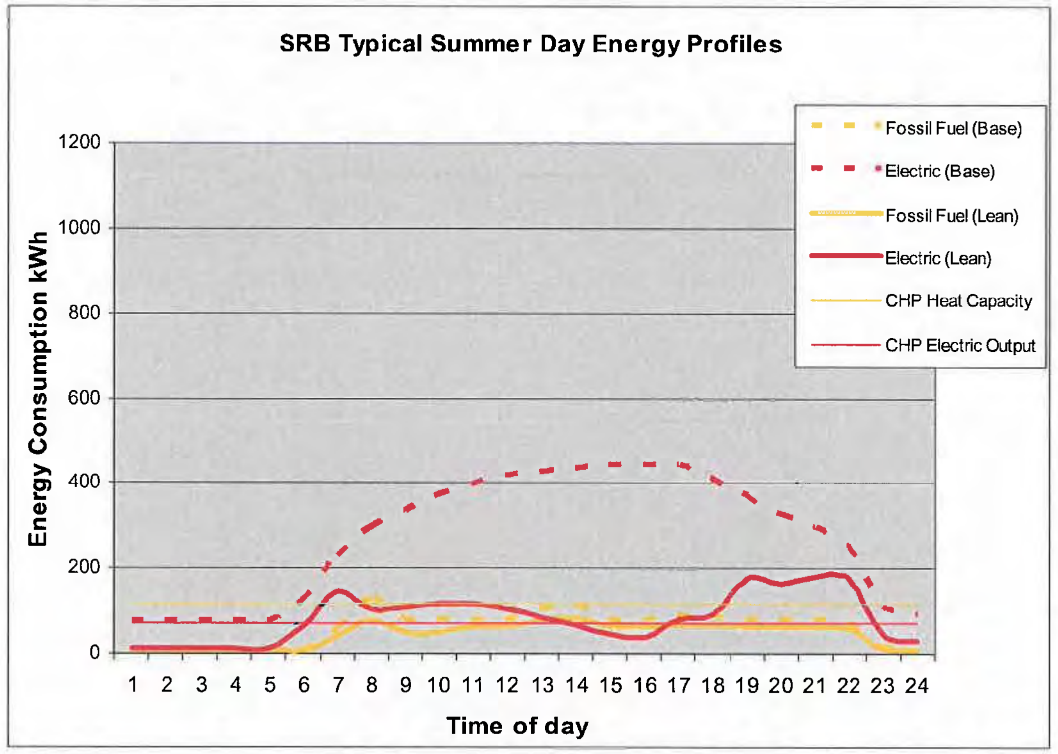
Indicative energy consumption profiles have been produced for building operation on typical days during the heating season (winter), mid-season conditions (spring / autumn) and cooling season (summer). The Energy profiles demonstrate how the proposed 'Lean' design measures will reduce the anticipated fossil fuel and electricity demands on an hourly basis.

It must be remembered, however, that the profiles are based upon typical days in each season, the peak loads will be much higher. It should also be noted that the heating profiles include heating for domestic hot water as the demand occurs. The proposed scheme incorporates hot water storage, which will in effect reduce the peaks and create a more even demand.

These demand profiles suggest that it may be appropriate to consider combined heat and power systems capable of providing 70kW$_e$ and 115kW$_{th}$ for the SRB.







6. CHP GENERAL TYPES AND APPLICATION

All forms of combined heat and power (CHP) involve the generation of electricity on site and the recovery and use of the waste heat . The following factors contribute to a cost effective and efficient application of the technology

- Long running hours at close to full electrical load
- A year round use for the recovered heat
- A use for the recovered heat that is close to the CHP unit minimising distribution costs

One of the first widespread commercial applications for CHP was hotels where a year round high demand for hot water provided a good use for the recovered heat. In most other new buildings that have heat recovery on the fresh air there is a limited demand for heat for space heating other than on the colder winter days, and early in the mornings. Large modern buildings tend to need cooling more than they need heating. For this reason the waste heat is sometimes used to generate cooling via absorption chillers. This is known as combined cooling and heating and power (CCHP). The scale of the buildings and cooling capacities for the buildings at NUI Galway is generally below the bottom of the range of sizes for absorption chillers, at a point where either machines are not available that small or where their use is extremely expensive. The CCHP approach has not therefore been further considered.

A centrally located CHP serving all three building locations would benefit from the scale of the installation but the heat distribution costs to buildings so far apart we feel would be beyond the scope of the project and prohibitively expensive, and the approach has therefore been discounted.

6.1 OPTION 1 – GAS FIRED CHP

An assessment has been made of the potential of a gas-fired CHP scheme.

A CHP unit requires a constant electrical and heating demand in order that it operates for the maximum period of time to maximise it's benefit and financial viability. In times of low demand e.g. night time, the CHP can reduce it's output down to 60% without significantly reducing efficiency. In addition, excess heat can be transmitted to a hot thermal store. As a last resort, the CHP unit can be switched off.

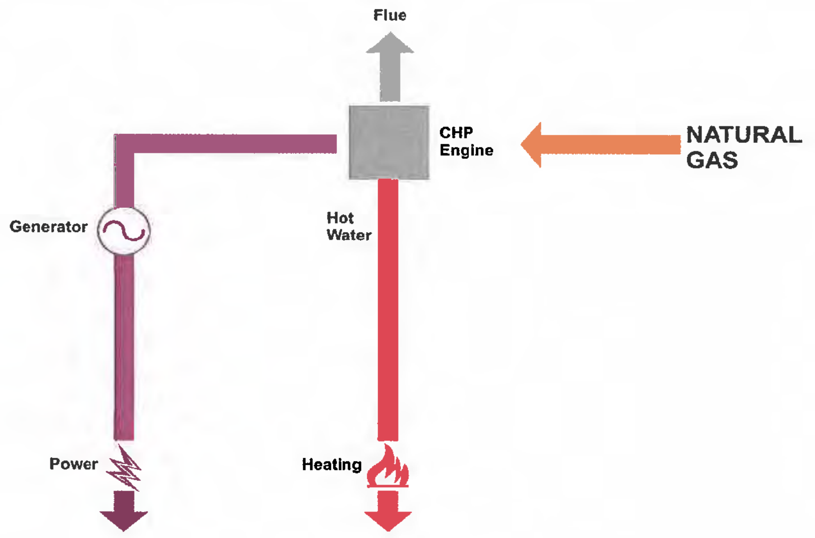
A relatively efficient CHP has been selected from manufacturer's data with a heat to power ratio typical of this size of CHP unit.

It is proposed that the CHP unit would run continuously controlled on a heat demand basis and exporting electricity to the grid where the output of the unit exceeds on site demand. By using this control regime there is no requirement to provide supplementary heat rejection equipment, and all heat and electricity generated will be used. The benefit due to electricity exported into the grid is included into the carbon reduction assessment.

The CHP unit would act as the lead boiler and would be supplemented by back up and top-up heating provided by gas fired boilers.

A small thermal store would be provided designed to store approximately 5 hours peak output from the CHP. The heat stored would allow peaks to be dealt with (such as early morning boost) with minimal heat input from gas boilers, and would generally provide a means of matching demand to output more closely.

The results of the analysis are shown in the table.



Gas Fired CHP			
	HSSB	CRF & TRF	SRB
Gas CHP Unit (kWe)	100	50	70
Capital Cost	112,420	95000	100,000
Annual Energy Consumption Savings (kWh/year)			
Electricity	497,588	357,958	441,228
Gas	-150,966	-116,478	-138,027
Total Annual Energy Savings	346,622	241,480	303,201
Annual Operating Cost Savings (€ /Year)			
Electricity	59,711	42,955	52,947
Gas	-7,711	-5,949	-7,050
Total Annual Cost Savings	52,000	37,006	45,898
Carbon Emissions			
Carbon Emissions Reduction (Tonnes/Year)	289.3	206.5	223.8
Carbon Emissions Reduction (% of Baseline Design)	18%	460%	16.5%
Carbon Cost Index (€/Tonnes/Year)	389	528	391
Simple Payback (Years)	2	3	2

6.2 OPTION 2 – BIO-FUEL CHP

An assessment has been made of the potential of a bio-fuel CHP scheme.

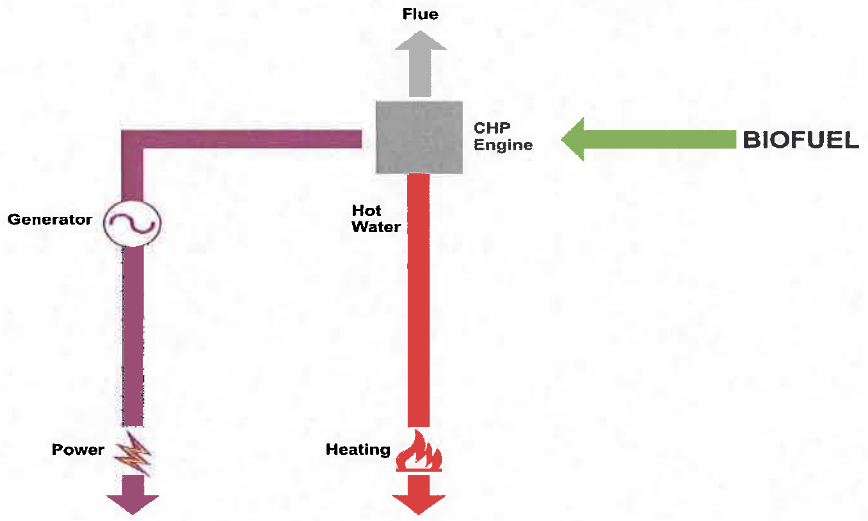
Essentially this scheme is identical to the gas fired CHP scheme except for the fuel used. Bio-fuel has a much lower Carbon content than natural gas and will therefore provide much higher CO2 savings.

Bio-fuel is considered almost carbon neutral because any CO2 released during combustion were captured during growth of the original plant material.

We have three significant concerns regarding the use of bio-fuel CHP

- The scale of the CHP plant each building with a reasonable electrical load of between 50- 100kW, and requirements for heating that means that the *Lean* building demand for heat can be low at night and very low in Summer is likely to make biomass particularly expensive.
- There are very few manufacturers of biomass CHP in the UK. The largest manufacturer we understand has recently ceased trading. Information that we have obtained to date regarding alternative is scant and does not provide us with confidence in them.
- Biomass CHP needs to be at ground level with good access for fuel delivery. This may well cause a problem at the CRF/TRF where space at ground level is more restricted.

The capital costs are likely to be around € 400,000 for a 100kWe CHP unit with a simple payback period of around 8 to10 years. We have not been able to establish manufacturers of units smaller than 100kWe.



Biomass Fired CHP			
	HSSB	CRF & TRF	SRB
Biomass CHP Unit (kWe)	83	41	58
Capital Cost	400000	400000	400000
Annual Energy Consumption Savings (kWh/year)			
Electricity	410,510	295,315	364,013
Gas	954,674	686,779	846,542
Biomass (Woodchip)	-1,187,103	-864,212	-1,058,047
Total Annual Energy Savings	178,082	117,882	152,508
Annual Operating Cost Savings (€ /Year)			
Electricity	49,261	35,438	43,682
Gas	48,760	35,077	43,237
Biomass (Woodchip)	-47,158	-34,331	-42,031
Total Annual Cost Savings	50,864	36,184	44,888
Carbon Emissions			
Carbon Emissions Reduction (Tonnes/Year)	428.1.7	307.7	379.5
Carbon Emissions Reduction (% of Baseline Design)	26.7%	42.7%	21.2%
Carbon Cost Index (€/Tonnes/Year)	934	1300	1154
Simple Payback (Years)	8	11	9

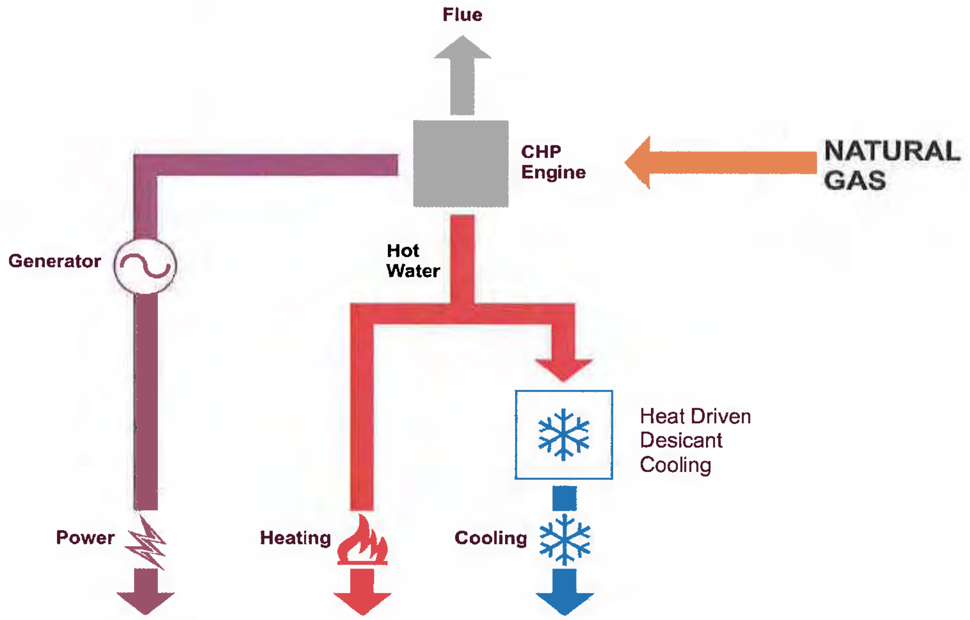
6.3 OPTION 3 – HEAT DRIVEN DESICCANT COOLING

A heat driven desiccant cooling system has been considered for the HSSB displacement ventilation systems. The system is capable of using "waste heat" low temperature hot water from the CHP to generate cooling for the ventilation system serving the library, thus removing the need for chilled water cooling from chillers.

A further benefit is the increased thermal efficiency during the heating season. At an outside design condition of -2°C the air handling units can deliver supply air to the room without the need for heat from the boilers.

The system is particularly well suited for use with a CHP plant since it reduced the demand for heat in winter and increases the demand in summer.

The resulting improvement in operation of the Gas CHP considered for the HSSB is shown in the table.



Gas Fired CHP (with Desiccant Cooling)		
	HSSB without Desiccant Cooling	HSSB with Desiccant Cooling
Gas CHP Unit (kWe)	100	100
Capital Cost	112,420	300,000
Annual Energy Consumption Savings (kWh/year)		
Electricity	497,588	583,406
Gas	-150,966	-177,003
Total Annual Energy Savings	346,622	406,403
Annual Operating Cost Savings (€ /Year)		
Electricity	59,711	97307
Gas	-7,711	-9,040
Total Annual Cost Savings	52,000	88267
Carbon Emissions		
Carbon Emissions Reduction (Tonnes/Year)	289.3	339.2
Carbon Emissions Reduction (% of Baseline Design)	18%	21.2%
Carbon Cost Index (€/Tonnes/Year)	389	884
Simple Payback (years)	2	3.4

7. *"LEAN"* & *"CLEAN"* BUILDING DESIGN

7.1 *"LEAN"* & *"CLEAN"* BUILDING SAVINGS

The table below summarises the anticipated benefits of adopting the 'Lean' & 'Clean' building design features.

In addition to those Lean options already recommended the additional Clean options recommendations are :-

- HSSB Gas CHP in combination with Desiccant cooling.
- CRF / TRF CHP not recommended
- SRB Gas CHP.

Technology	**HSSB**			**CRF & TRF**			**SRB**		
	Energy Cost (€ / Year)	CO_2 Emissions (Tonnes/Year)	% CO_2 Savings (of Baseline Building)	Energy Cost (€ / Year)	CO_2 Emissions (Tonnes/Year)	% CO_2 Savings (of Baseline Building)	Energy Cost (€ / Year)	CO_2 Emissions (Tonnes/Year)	% CO_2 Savings (of Baseline Building)
Baseline Consumption/Emission	316,781	1,603	-	149,536	720	-	372,245	1,792	-
Lean Design Savings	163,293	824	51%	59770	433	60%	118,907	985	52%
Clean Design Savings	88267	339	21.2%	-	-	-	45,898	255	14.3%
Lean & Clean Design Total Savings	256560	1163	72%	59,770	433	60%	164,805	932	69%

The overall Lean and Clean building design savings for the NUI Galway Biosciences project are estimated to be:-

A carbon dioxide emission saving of 2,162 Tonnes/Year, which represents a saving of 69% of the Baseline buildings emissions.

An annual energy cost saving of €481,135 / year.

8. RENEWABLE ENERGY

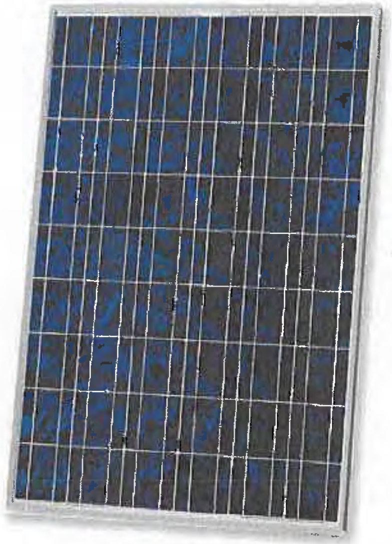
This section shows the results of analyses into various renewable technologies.

8.1 PHOTOVOLTAICS

PV panels must be located in a generally south facing position, ideally at about 30° to the horizontal. If located vertically, output is reduced by about 15%.

The scheme investigated is based upon installing a nominal 40 m^2 of (polycrystalline) PV panels horizontally on the roof of the new buildings. Such an installation can provide only a small percentage reduction in the overall carbon emissions for this development, as set out in the table opposite. It also is one of the least cost effective technologies in reducing carbon dioxide emissions. However, PV does provide a visible green label for the buildings.

The technology has been discounted on the basis of poor value.



Photovoltaics			
	HSSB	CRF & TRF	SRB
Polychrystalline PV panels and control gear			
Capital Cost (€)	35,974	35,974	35,974
Active area of panels (m2)	40.0	40.0	40.0
Annual Energy Consumption Savings (kWh/year)			
Electricity	3,060	3,060	3,060
Gas	0	0	0
Total Annual Energy Savings	3,060	3,060	3,060
Annual Operating Cost Savings (€ /Year)			
Electricity	367	367	367
Gas	0	0	0
Total Annual Cost Savings	367	367	367
Carbon Emissions			
Carbon Emissions Reduction (Tonnes/Year)	2.0	2.0	2.0
Carbon Emissions Reduction (% of Baseline Design)	0.12%	0.3%	0.11%
Carbon Cost Index (€/Tonnes/Year)	21,161	21,161	21,161
Simple Payback (years)	98	98	98

8.2 SOLAR HOT WATER HEATING

Solar hot water heating is a well proven technology. Compared to other renewable technologies it is relatively inexpensive, cost effective with low maintenance..

Solar hot water panels should be located in a generally south facing position, ideally at about 30° to the horizontal. If located vertically, output is reduced by about 15%.

Whilst the technology is relatively cost effective the savings in energy, carbon emissions, and money will always be restricted by the fact that a low amount of energy is utilised to produce domestic hot water. The potential impact upon the overall building energy consumption will therefore always be equally limited. Where CHP is provided waste heat will generally be available, thus negating most or all of the potential benefit of solar hot water heating. Solar hot water heating has been considered only for the CRF/TRF building where CHP has not been proposed.

The scheme investigated is based upon installing a nominal 50 m^2 of high efficiency evacuated tube collectors on the roof of the new CRF/TRF building.

Such an installation can provide only a small percentage reduction in the overall carbon emissions for this development. As can be seen in the table opposite the carbon emission reductions for the CRF/TRF are only predicted to be around 0.5% of the Lean Emissions, or 0.4% of the Baseline Emissions.

However, solar hot water does provide a visible green label for the building.

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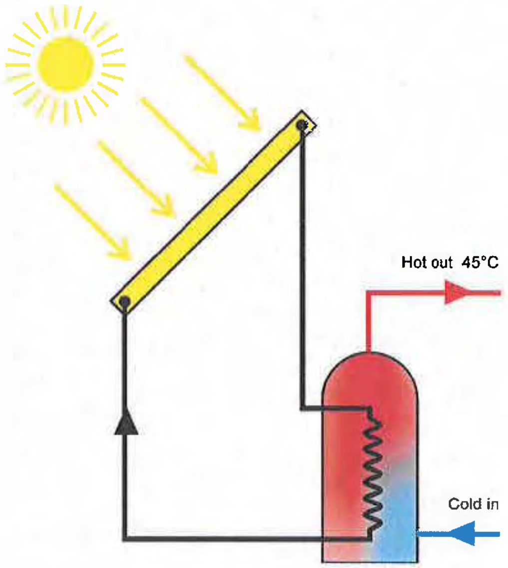


Solar Hot Water			
		CRF & TRF	
Evacuated Tube			
Active area of panels (m2)		50.0	
Capital Cost (€)	N/A	56,210	N/A
Annual Energy Consumption Savings (kWh/year)			
Electricity		0	
Gas		21,347	
Total Annual Energy Savings		21,347	
Annual Operating Cost Savings (€ /Year)			
Electricity		0	
Gas		1,090	
Total Annual Cost Savings		1,090	
Carbon Emissions			
Carbon Emissions Reduction (Tonnes/Year)		4.3	
Carbon Emissions Reduction (% of Baseline Design)		0.7%	
Carbon Cost Index (€/Tonnes/Year)		12,970	
Simple Payback (Years)	-	52	-

8.3 WIND TURBINES

Wind turbines produce electricity directly from the energy in wind. This is then fed into the buildings electrical system via control gear, or into the grid system again via control gear accommodated within a building.

Two types of wind turbine are available; horizontal axis and fixed vertical axis. The former tend to be noisy and produce vibration. The latter are quieter in operation and more suited to installation on buildings but are generally less efficient and more expensive. The three images below show a small simple horizontal axis unit, a medium sized fixed vertical axis unit and a larger horizontal axis unit.

The West of Ireland is noted for its winds speeds but the speeds can be significantly reduced close to ground level in urban areas leading to possible reductions in output.

There are issues of noise, vibration and appearance especially with anything other than the smallest and well selected unit being mounted on buildings.

Initial assessments suggest that the payback periods for any type of wind turbine will be very long and they are therefore not generally recommended as part of the NUI Galway Biosciences development. Larger wind turbines do however tend to be more economic and produce electricity more efficiently than the two smaller units shown. The University may therefore wish to consider a larger unit not specifically connected with any of the new buildings but providing renewable electrical energy to the general campus.

Wind Turbines			
Turbine	Rutland 913	Turby BV	Aircon HAWT
kWe duty (at rated wind speed)	0.09	2.5	10.0
Rotor diameter (m)	0.91	1.99	7.10
Hub Height (m)	6.5	6.0-7.5	12.0-30.0
Costs	€7500	€28000	€Not Available
Annual Energy Consumption Savings (kWh/year)			
Electricity	274	2,881	29,747
Gas	0	0	0
Total Annual Energy Savings	274	2,881	29,747
Annual Operating Cost Savings (€ /Year)			
Electricity	33	346	3,570
Gas	0	0	0
Total Annual Cost Savings	33	346	3,570
Carbon Emissions			
Carbon Emissions Reduction (Tonnes/Year)	0.2	1.9	19.1
Carbon Emissions Reduction (% of Baseline Design)	<1.0%	<1.0%	<1.0%
Carbon Cost Index (€/Tonnes/Year)	37,500	14,737	NA
Simple Payback (years)	227	80	

All percentage Carbon Savings are related to the building with the lowest Baseline Design carbon emissions (CRF/TRF).

9. CONCLUSIONS

A range of energy saving measures and technologies have been considered, The recommended measures are scheduled below.

The *Lean* measures are in today's environmentally aware society become routine good practice. They tend to be the most cost effective measures, with the *Clean* measures the next most effective, followed by the *Green* measures. Currently the major impact in reducing energy consumption and carbon emissions will be made by the *Lean* and *Clean* measures. The Green measures will only make a significant impact on a build that has already been made very energy efficient.

9.1 ENERGY EFFICIENCY MEASURES (LEAN)

The following passive and active energy efficiency measures are recommended; all these measures are recommended irrespective of which of the energy strategies is pursued.

- Enhanced U values of building envelope, and high levels of air tightness.
- Optimised glazing design to improve day-lighting, reduce overheating, and to minimise the use of air conditioning
- Use of nightime cooling to naturally ventilated areas
- Low energy white goods
- Variable Flow Air & Water Systems
- Low energy lighting with presence detection and photo cell dimming control
- Improved chiller efficiency
- Air heat recovery in apartments and hotel
- DC motors on fan coil units
- Power factor correction

Together, these measures are predicted to reduce total carbon dioxide emissions from the whole development by around 54% when compared to the *Baseline* emissions.

9.2 CHP ENERGY (CLEAN)

Various forms of CHP have been considered. Gas fired CHP is recommended for the SRB and for the HSSB. To achieve a high level of heat utilisation the CHP proposed for the library is used in conjunction with a desiccant cooling system. The desiccant cooling system has the effect of reducing electrical energy consumption and the size of the library chiller installation whilst utilising waste heat to generate cooling in Summer.

Where CHP has not been recommended on the CRF/TRF solar collectors can be used to substantially reduce the demand for fossil fuel heat.

Together, these measures (lean and clean) are predicted to reduce total carbon dioxide emissions from the whole development by around 59% when compared to the *Baseline* emissions.

Further reductions could be achieved by the use of biomass CHP and these should be considered further prior to moving forward to the next stage of design

9.3 RENEWABLE ENERGY TECHNOLOGIES

The totally renewable technologies are capable of further reducing carbon emissions , but they tend to deliver the least carbon reductions per euro spent. The least costly is solar water heating and this is recommended for the CRF/TRF where CHP is least readily applied.

Wind is present for much of the time on the West coast of Ireland and wind energy could be considered further , however it has no strong link to any of the buildings, and should the university wish to consider this option further then this should probably be done as a separate project..

Together, these measures (lean clean, and green) are predicted to reduce total carbon dioxide emissions from the whole development by around 69% when compared to the *Baseline* emissions; the benefit in carbon reduction from solar hot water being around 1%.

In summary the overall position is summarised below

Technology	**HSSB**			**CRF & TRF**			**SRB**		
	Energy Cost (€ / Year)	CO_2 Emissions (Tonnes/Year)	% CO_2 Savings (of Baseline Building)	Energy Cost (€ / Year)	CO_2 Emissions (Tonnes/Year)	% CO_2 Savings (of Baseline Building)	Energy Cost (€ / Year)	CO_2 Emissions (Tonnes/Year)	% CO_2 Savings (of Baseline Building)
Baseline Consumption/Emission	316,781	1,603	-	149,536	720	-	372,245	1,792	-
Lean Design Savings	163,293	824	54%	59770	433	60%	118,907	985	55%
Clean Design Savings	88,267	339	21.2%	-	-	-	45,898	256	14.3%
Green Design Savings	-	-	-		4.3				
Lean, Clean & Green Design Total Savings	256,560	1163	72%	59,770	437	60%	164,805	1241	69%

The overall lean and clean building design savings for the project are estimated to be:-

A carbon dioxide emission saving of 2,166 Tonnes/Year, which represents a saving of 71% of the Baseline buildings emissions.

An annual energy cost saving of €482,225 / year.

APPENDIX 1

ANNUAL ENERGY CONSUMPTION

NUI Galway

Initial Estimates of Energy Consumption

Laboratories

Energy consumption in laboatories can vary widely. A simple very basic typical laboratory will typically have an energy consumption of around 335 kWh/sq.m/year. It is recommended that the Good Practice energy levels are used for "new build". A complex laboratory may have an energy consumption of between 500-1000 kWh/sq.m/year.

The main factors that contribute to the difference in energy consumption between a simple laboratory and a more complex laboratory are:-

- Hours of operation - a simple laboratory is taken to be in operation 55 hours a week.
- The extent to which the laboratory needs to be mechanically ventilated, and air conditioned
- The enenergy consumed by the processes, and equipment in use in the laboratories.

The tables below apply the above factors to the laboratories at NUI Galway to provide an initial assessment of the order of likely energy consumption.

	Typical Annual Energy Consumption (New Build)		
	SRB	**CRF**	**TRF**
TypicalNew Build (Good Practice) Simple Laboratory Annual Energy Consumption (kwh/sq.m/yr)	270	270	270
Energy consumption factor based upon anticipated hours of operation.Hours of operation simple laboratory (2860h/ year).	2	2	1.5
Revised Energy consumption	540	540	405
Extent of HVAC Factor Correction to Energy consumption	653	621	466
Equipment	713	651	506
Total Typical Anticipated Energy Consumption (kwh/sq.m/yr)	**713**	**651**	**506**

Note fossil fuel typicall will acount for around 60% of the energy consumed and electricity for around 40%.

Hours of Operation

SRB

Approx 16% at 24 hr operation and 84% at 0800 to 2200 and 7 days per week = (0.16 x 24 x 7 x 52) + (0.84 x 14 x 7 x 52)
= 5679 hrs
Factor = 5679/2860 = 1.99 say 2

CRF

Say 50% of area operates 24 hours 7 days/ week for patients and support. Remainder 0800 to 1800 hrs and 5 days/week. = (0.5 x 24 x 7 x 52) + (0.5 x 10 x 5 x 52) = 5668 hrs
Factor say 2

TRF

Operates 0800 to 2000 and 5 days/week = 12 x 7 x 52 = 4368
Factor = 1.5

Extent of Mechanically Ventilated and Air Conditioned Spaces

Mechanically ventilated and air conditioned spaces have been taken to on average consume 30% more energy than naturally ventilated spaces heated by radiators.

	% Mech Vent/AC Space
SRB	70
CRF	50
TRF	50

Equipment

Allowances :-	kWh/sq.m/year	
SRB	60	Includes mass spectrometer
CRF	30	
TRF	40	

NUI Galway

Initial Estimates of Energy Consumption

Library

	Fossil Fuel kWh/sq.m/year	Electricity kWh/sq.m/year	Total kWh/sq.m/year
Typical Energy Consumption (Air conditioned library)	173	292	465
Add for Galway Archive areas 15 kWh/sq.m/year		15	480
TotalTypical Anticipated Energy Consumption			**480**
Good Practice would reduce the above by around 200 kWh/sq.m/year			*464*

Factor Adjustments for a Research Library open 24 hours a day

Nightime - very low occupancy level defined as 2200 hours to 0800 hours

During this period

Library ventilation systems will be "off".

Library lighting over desk positions will be controlled by presence detection, and corridors/communication routes will be on.
Small power energy will be proportionate to number of occupants/lighting.
Heating will be controlled to achieve internal comfort conditions.
Cooling will be "off".

Night Operation Energy Factors

Electricity	0.15
Fossil Fuel	0.2

Hours of Useage Energy factor

Typical Universty Library 0900 to 2100
Research Library 24 hour
Factor 2

	Fossil Fuel kWh/sq.m/year	Electricity kWh/sq.m/year	Total kWh/sq.m/year
Typical New(Good Practice Library Energy Consumpti (Air conditioned library)	173	292	465
Fossil fuel additional energyis 245 x 2 x 0.20	98		
Electricity additional energy 404 x 2 x 0.15		121	
Add for Galway Archive areas 15 kWh/sq.m/year		15	
TotalTypical Anticipated Energy Consumption	**271**	**428**	**699**

Note

The base energy model is assumed to have been based upon a minimum fresh air HVAC system.
The displacement vent system modelled is based upon 100% fresh air for the reading areas.
If assumption is correct - it will reduce the order of accuracy of the estimates for the BSSB as follows:-

- Total gas energy consumption, and energy costs low.
- Energy savings minimal impact - about right.
- Percentage carbon emissions minimal impact - about right.

APPENDIX 2

DESICCANT COOLING

DesiCool™

Desiccant cooling system
MCUI series for indoor installation

EQUIPMENT

DesiCool™

- Uses heat to cool
- Low running costs
- Easy to install and maintain – no experts needed
- CFC free
- No compressors and no condensers with fans
- Typically 70% reduction in installed electric power
- 90% heat recovery efficiency
- Well proven design
- Sole supplier responsibility for the complete unit

DesiCool™ is a complete air-conditioning system based on desiccant cooling. Although it uses no compressors, it has a capacity similar to conventional CFC-based systems. It is possible to cool ambient air at a temperature of 30 °C down to 15 °C. For the cooling process to function properly during the summer months, additional heat is needed. The more heat added, the cooler it gets! Excess heat can be made good use of.

DesiCool has many advantages. It uses heat as the energy source for the cooling process, not electricity. In most cases, there is no need for postheating to heat the air in winter because the heat recovery efficiency is so extremely high. These two advantages mean low running costs. And, no compressors means that maintenance can be taken care of by in-house staff.

DesiCool is a perfect solution for air flows above 2 m³/s. In systems having chilled beams, the dew point is controlled without undercooling the supply air. A cooling coil for dehumidification is not needed.

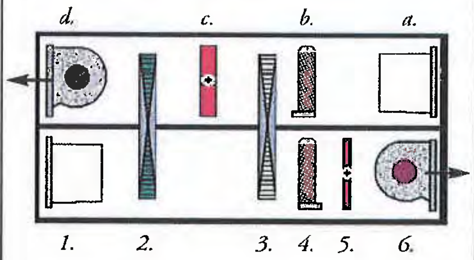
The desiccant cooling technology

Ambient air is dehumidified in the desiccant wheel and then sufficiently cooled in the thermal wheel. It then reaches desired supply conditions by additional cooling in an evaporative cooler.

Exhaust air is cooled in an evaporative cooler. As it passes through the thermal wheel, it picks up heat from the supply air. It is then further heated to typically 55 °C using a heating coil. This hot air expunges the moisture from the desiccant wheel and re-generates the wheel.

Exhaust-air side

a. Filter
b. Evaporative cooler
c. Regeneration coil
d. Exhaust-air fan



Supply-air side

1. Filter
2. Desiccant wheel
3. Thermal wheel
4. Evaporative cooler
5. Reheating coil
6. Supply-air fan

05/03/2009

Lizzy Summer

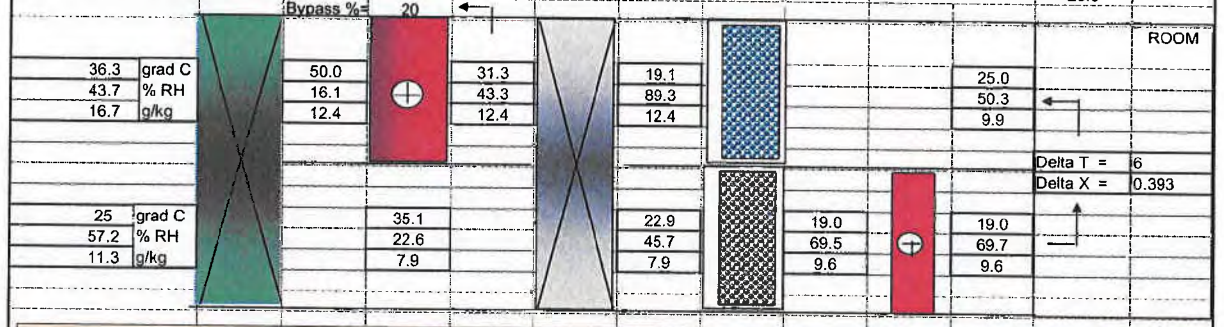
PROJECT **Roger Preston & Ptns Galway Bioscience Labs.**

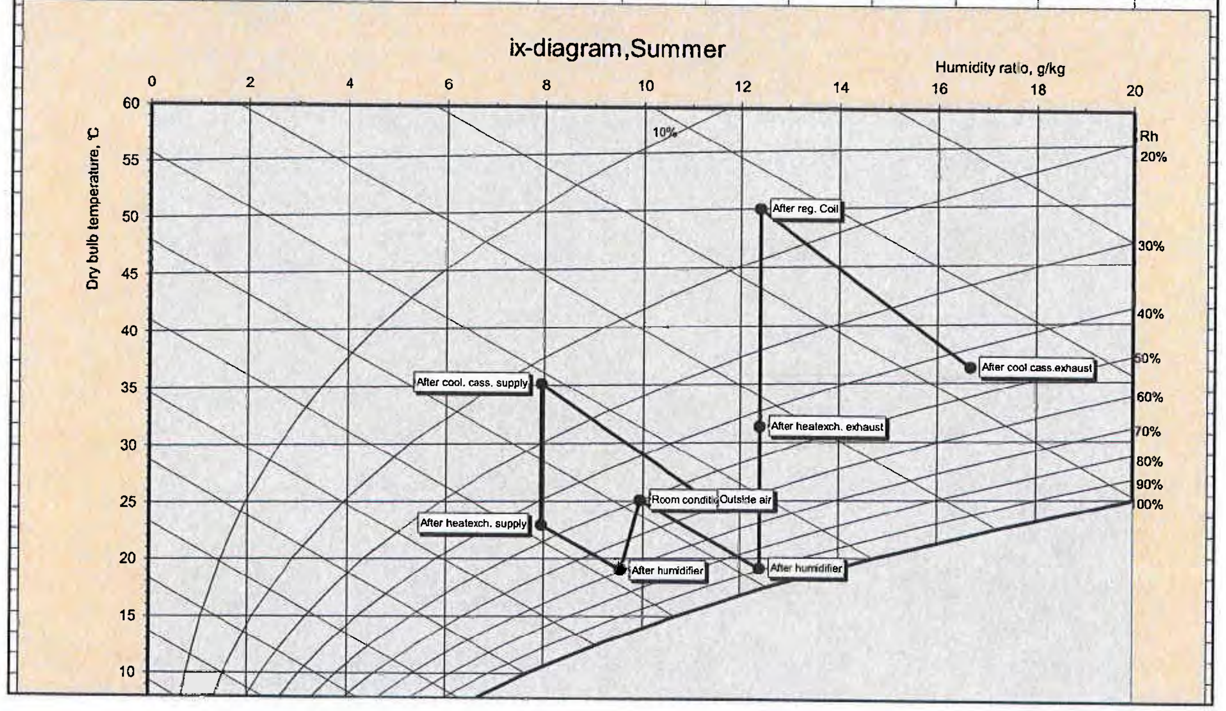
	Tdry ℃	X dry g/kg	RH %	Px,dry	Psat,wet	Hdry	Hwet	Twet	Pwet	Xwet
Outside air	25.0	11.34	57	1.8	3.2	54.1	54.3	19.0	2.2	13.8
After cooling cass.	35.1	7.9	23	1.3	5.7	55.8	56.4	19.6	2.3	14.4
After heat exchanger	22.9	7.9	46	1.3	2.8	43.4	43.6	15.5	1.8	11.0
After humidifier	19.0	9.6	70	1.5	2.2	43.5	43.6	15.5	1.8	11.0
After supply coil	19.0	9.6	70	1.5	2.2	43.4	43.5	15.5	1.8	11.0
Exhaust air	25.0	9.9	50	1.6	3.2	50.6	50.8	17.9	2.1	12.9
After humidifier	19.1	12.4	89	2.0	2.2	50.8	50.8	17.9	2.1	12.9
After heat exchanger	31.3	12.4	43	2.0	4.6	63.4	63.7	21.7	2.6	16.4
After reg.coil	50.0	12.4	16	2.0	12.3	82.7	83.8	26.7	3.5	22.3
After cooling cass.	36.3	16.7	44	2.64	6.0	79.5	79.9	25.8	3.33	21.1
Reg air	36.2	16.7								
Purge air	44.6	11.9								
Internal load Delta T	6									
Internal load Delta X	0.393									

	Airfl. m3/s	Pr.loss Pa	Eff %	Max eff %	Steps %	Veloc m/s	Face sqm	Width cm	Hight cm	Nom eff %
Air filter supply	9.8	279				3.1	3.2	177.6	177.6	
Cooling cass.supply	9.5	170				2.8	3.4	294.6		
Heat exchang.supply	9.3	140	76.3	76.3	100	2.7	3.5	300		
Humidifier supply	9.3	74	52.3	83.1	63	3.2	2.9	240	150	85
Supply coil	9.3	51				4.3	2.1	176	122	
Supply fan	9.3	17				9.3	1.0	100	100	
Supply total		732								
Air filter exhaust	9.3	270				2.9	3.2	177.6	178	
Humidifier exhaust	9.3	74	83.1	83.1	100	3.2	2.9	240	150	85
Heat exchanger exhaust	9.3	140	76.3	76.3	100	2.7	3.5	300		
Bypass cooling cass.	1.9		20.0							
Reg. coil	7.7	176				3.6	2.1	176	122	
Cooling cass. exhaust	7.7	137				2.3	3.4	294.6		
Exhaust fan	9.8	57				9.8	1.0	100	100	
Exhaust total		854								

	Wat.in C	Wat.out C	Flow l/s	Power kW	Freshw l/m	Evap. l/m	Top sqm
Supply coil							
Reg. coil	80	60	2.05	172.1			
Humidifier supply					14.4	1.1	0.48
Humidifier exhaust					14.4	1.6	0.48

		Room grad
Displ.vent.	H>4m	21.4
Displ.vent.	H=2,6-4m	23.2
Mixed vent.		25.0





05/03/2009

Lizzy Winter

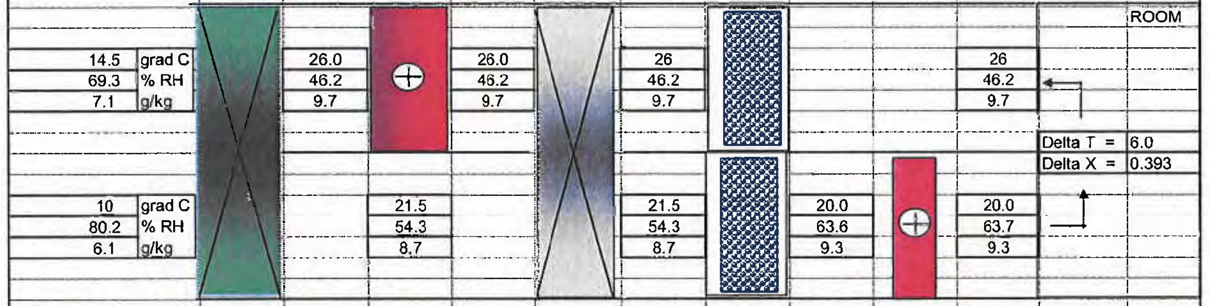
Project Roger Preston Galway Biscience Labs										
	Tdry ℃	Xdry g/kg	RH %	Px,dry	Psat,wet	Hdry	Hwet	Twet	Pwet	Xwet
Outside air	10.0	6.1	80	1.0	1.2	25.5	25.5	8.3	1.1	6.8
After Cooling cass.	21.5	8.7	54	1.4	2.6	43.8	44.0	15.6	1.8	11.1
After Heat exchanger	21.5	8.7	54	1.4	2.6	43.8	44.0	15.6	1.8	11.1
After Humidifier	20.0	9.3	64	1.5	2.3	43.8	44.0	15.6	1.8	11.1
After Supply coil	20.0	9.3	64	1.5	2.3	43.8	43.9	15.6	1.8	11.1
Exhaust air, Room cond.	26.0	9.7	46	1.6	3.4	51.0	51.2	18.1	2.1	13.0
After Humidifier	26.0	9.7	46	1.6	3.4	51.0	51.2	18.1	2.1	13.0
After Heat exchanger	26.0	9.7	46	1.6	3.4	51.0	51.2	18.1	2.1	13.0
After Reg.coil	26.0	9.7	46	1.6	3.4	51.0	51.2	18.1	2.1	13.0
After Cooling cass.	14.5	7.1	69	1.1	1.7	32.6	32.7	11.4	1.3	8.4

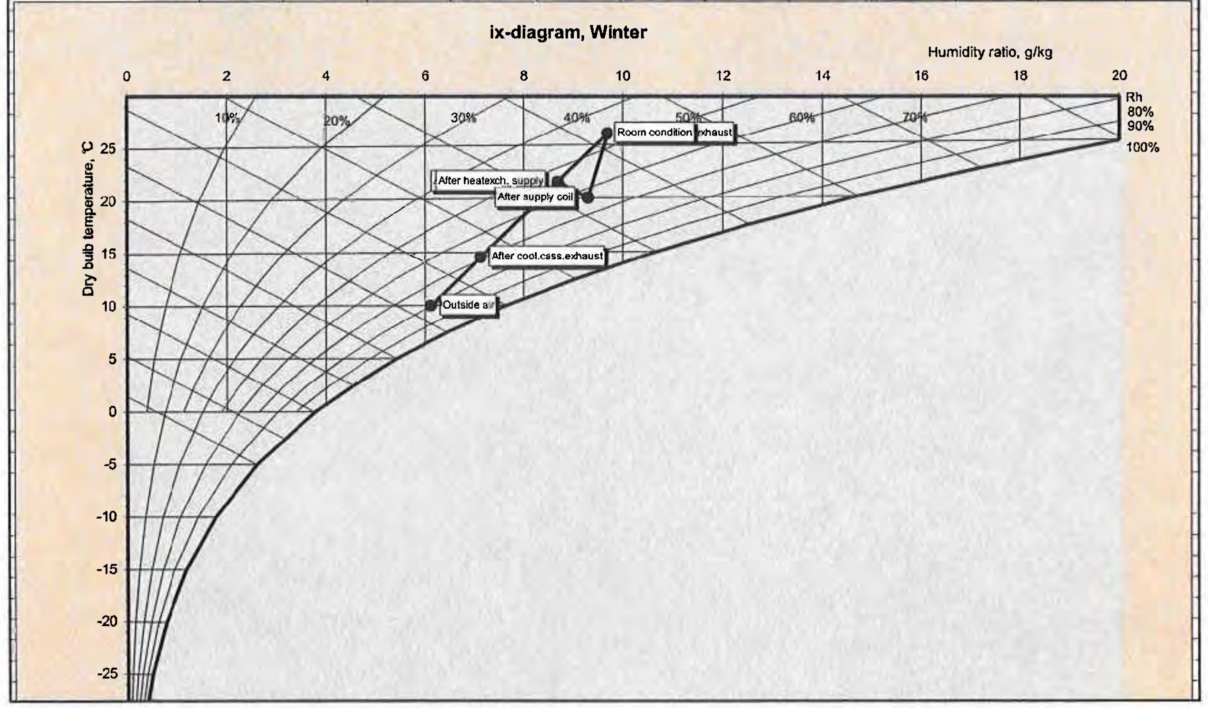
Internal load Delta T	6.0	
Internal load Delta X	0.393	
Reg.coil Delta T	0.0	No ice !

	Airfl. m3/s	Pr.loss Pa	Eff %	Max Eff %	Steps %	Veloc. m/s	Face sqm	Width cm	Hight cm	Nom. eff %
Air filter supply	9.8	245				2.6	3.8	180	210	
Cooling cass.supply	9.5	200	71.9	72.6	99	3.3	2.9	270		
Heat exchang.supply	9.3	171	0.0	73.1	0	3.3	2.9	270		
Humidifier supply	9.3	61	25.1	83.7	30	2.9	3.2	180	210	85
Supply coil	9.3	35				3.5	2.7	176	152	
Supply fan	9.3	26				11.5	0.8	90	90	
Supply total		737								
Air filter exhaust	9.3	236				2.5	3.8	180	210	
Humidifier exhaust	9.3	61				2.9	3.2	180	210	85
Heat exchanger exhaust	9.3	171	0.0	73.1	0	3.3	2.9	270		
Reg. coil	9.5	176				3.6	2.7	176	152	
Cooling cass. exhaust	9.5	200	71.9	72.6	99	3.3	2.9	270		
Exhaust fan	9.8	87				12.1	0.8	90	90	
Exhaust total		931								

	Wat.in C	Wat.out C	Watflow l/s	Power kW	Freshw l/m	Evap. l/m	Top sqm
Supply coil	90	50	0.00	-0.4			
Reg. coil	90	50	0.00	0.0			
Humidifier supply					10.8	0.4	0.36

		Savings in kW vs	Savings in kW vs		
Supply coil power	kW	Heat exchanger only	No heat exch.		Room grad
Desicool	-0.4	-18.5	112.0	Displ.vent. H>4m	22.4
Heat exchanger only	-18.8			Displ.vent. H=2,6-4m	24.2
No heat exchanger	111.6			Mixed vent.	26.0





05/03/2009

Lizzy Winter

Project Roger Preston Galway Biscience Labs										
	Tdry ℃	Xdry g/kg	RH %	Px,dry	Psat,wet	Hdry	Hwet	Twet	Pwet	Xwet
Outside air	-4.0	2.7	96	0.4	0.5	2.7	2.7	-4.2	0.4	2.8
After Cooling cass.	12.0	3.7	43	0.6	1.4	21.6	21.6	6.5	1.0	6.0
After Heat exchanger	20.0	3.7	26	0.6	2.3	29.7	29.9	10.2	1.2	7.8
After Humidifier	20.0	3.7	26	0.6	2.3	29.7	29.9	10.2	1.2	7.8
After Supply coil	20.0	3.7	26	0.6	2.3	29.7	29.9	10.2	1.2	7.8
Exhaust air, Room cond.	26.0	4.1	20	0.7	3.4	36.8	37.1	13.1	1.5	9.4
After Humidifier	26.0	4.1	20	0.7	3.4	36.8	37.1	13.1	1.5	9.4
After Heat exchanger	18.0	4.1	32	0.7	2.1	28.7	28.8	9.8	1.2	7.5
After Reg.coil	18.0	4.1	32	0.7	2.1	28.7	28.8	9.8	1.2	7.5
After Cooling cass.	2.0	3.1	71	0.5	0.7	9.8	9.8	0.2	0.6	3.8

Internal load Delta T	6.0	
Internal load Delta X	0.393	
Reg.coil Delta T	0.0	No ice !

	Airfl. m3/s	Pr.loss Pa	Eff %	Max Eff %	Steps %	Veloc. m/s	Face sqm	Width cm	Hight cm	Nom. eff %
Air filter supply	9.8	245				2.6	3.8	180	210	
Cooling cass.supply	9.5	200	72.6	72.6	100	3.3	2.9	270		
Heat exchang.supply	9.3	171	57.0	73.1	78	3.3	2.9	270		
Humidifier supply	9.3	61	0.0	83.7	0	2.9	3.2	180	210	85
Supply coil	9.3	35				3.5	2.7	176	152	
Supply fan	9.3	26				11.5	0.8	90	90	
Supply total		737								
Air filter exhaust	9.3	236				2.5	3.8	180	210	
Humidifier exhaust	9.3	61				2.9	3.2	180	210	85
Heat exchanger exhaust	9.3	171	57.0	73.1	78	3.3	2.9	270		
Reg. coil	9.5	176				3.6	2.7	176	152	
Cooling cass. exhaust	9.5	200	72.6	72.6	100	3.3	2.9	270		
Exhaust fan	9.8	87				12.1	0.8	90	90	
Exhaust total		931								

	Wat.in C	Wat.out C	Watflow l/s	Power kW	Freshw l/m	Evap. l/m	Top sqm
Supply coil	90	50	0.00	0.3			
Reg. coil	90	50	0.00	0.0			
Humidifier supply					10.8	0.0	0.36

		Savings in kW vs	Savings in kW vs		
Supply coil power	kW	Heat exchanger only	No heat exch.		Room grad
Desicool	0.3	23.0	267.6	Displ.vent. H>4m	22.4
Heat exchanger only	23.3			Displ vent. H=2,6-4m	24.2
No heat exchanger	267.8			Mixed vent.	26.0