

Tornagrain

A Planned Town for the Highlands

Energy Strategy



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Executive Summary

Synopsis

This report considers potential low to zero-carbon and renewable energy strategies for the development of a new community at Tornagrain, close to Inverness Airport on behalf of Moray Estates Development Company Ltd (MEDCO). The Tornagrain Masterplan proposals are understood to comprise an estimated 4,960 homes, 4 primary schools, a secondary school and additional retail, commercial and community facilities. This report considers the inclusion of low to zero carbon and renewable energy technologies to meet emerging national renewable energy policy and the probable impact of the phasing strategy given anticipated changes to sustainability targets in Scotland over the design and build programme. This report summarises the consideration of a wide selection of options and presents a series of potential solutions with an appropriate balance of maximising efficiency, matching supply and demand, buildability and programme, seeking to progressively increase energy from renewable sources, and achieving a good level of carbon savings within a framework of commercial and operational viability.

This report presents a provisional solution which is challenging yet achievable. Furthermore it should be understood that technologies are constantly evolving and as such changes are likely to occur over the lifetime of the Tornagrain development and so future improvements and amendments at detail design and pre-construction should be fully embraced. It is accepted that the targets and objectives in a national and international framework will be regularly reviewed. By necessity therefore this preliminary energy strategy considers current and estimated changes to policy and technologies and is therefore not a specific finalised detailed design.

This report is based on the following information:

- Climate Change Consultation on Proposals for a Scottish Climate Change Bill (2008)
- A Low Carbon Building Standards Strategy For Scotland – Sullivan Report (2007)
- Scottish Planning Policy (SPP6)
- Highland Council Renewable Energy Strategy
- Integrating Renewable Energy Into New Developments: Toolkit for Planners, Developers and Consultants (2004)
- Initial Tornagrain Town Development Energy Strategy (Fulcrum Consulting)
- Renewable Energy Sources for Buildings CIBSE TM38 (2006)

This study assumes estimated phased performance standards for the fabric and construction of residential dwellings that should be adopted to achieve anticipated minimum energy

consumption and carbon reduction standards over the 30 year build programme of Tornagrain.

It should be borne in mind that any potential reductions in energy usage for the Tornagrain development listed within this report is indicative only, derived from estimates and rule of thumb calculations from the Chartered Institute of Building Service Engineers, British Standards and the Building Services Research and Information Association. Detailed SAP, SBEM and energy demand assessment calculations on the basis of full detailed development proposals have not been completed at this time. Actual energy usage patterns of the end users will likely vary from those predicted in this report and would certainly affect the extent to which actual carbon savings are achieved over the lifetime of the site. Changing the behaviour of occupants can play an important part in reducing energy consumption and education in the form of building and home 'user-guides' can inform occupants how best to use the home in an efficient way and promote reduction in resource consumption.

Potential strategies within this report have been derived from estimated energy consumption based on a phased programme of improved energy efficiency measures in accordance with anticipated building regulation and national carbon reduction policy minimum standards.

Proposed Energy Strategy for Tornagrain

Any energy strategy for Tornagrain is anticipated to be required to deliver significant carbon savings, including zero-carbon development beyond 2016. WYG Future has developed a preliminary strategic energy strategy capable of delivering a sustainable community at Tornagrain, in accordance with anticipated changing national policy and building regulation standards.

This energy strategy can only be realised if a phased programme of energy efficiency measures are implemented to reduce total site energy demand in line with anticipated national carbon reduction policy and building regulation standards (this will reduce the burden on renewable technologies). Step changes in the requirements for enhanced specifications are anticipated in 2010, 2013, 2016 and 2030.

A phased reduction in CO₂ is targeted from onsite renewable energy generation at Tornagrain, through integrating an appropriate low to zero carbon and renewable energy strategy, again in accordance with anticipated step changes in 2010, 2013, 2016 and 2030.

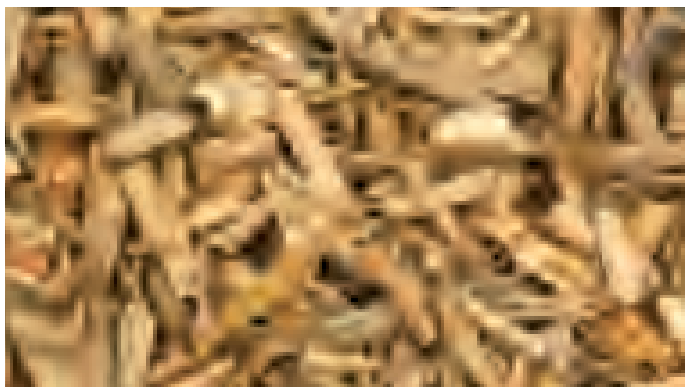
WYG Future has considered two alternative energy strategies for Tornagrain, these are detailed in Appendix B and C of this report.



Tornagrain Provisional Energy Strategy – Site Wide District Heating and Building Integrated Renewables

The Tornagrain preliminary energy strategy is based on a site wide district heating network with multiple energy centres located strategically around Tornagrain to minimise distribution losses and allow emerging technologies and as yet undetermined energy demand profiles to be effectively addressed. Initially this is likely to be in the form of a series of small independent networks eventually becoming interconnected over the course of the build programme to provide greater efficiency and security.

- Prior to 2016 networks would be led by modular gas fired CHP engines sized to meet a progressively increasing base thermal load in line with the build programme of Tornagrain, delivering significant reduction (>20%) in carbon emissions to meet anticipated requirements, however some building integrated renewables (such as photovoltaic cells and/or roof-mounted micro-wind turbines) might be included to further reduce annual carbon emissions before, and certainly after 2013.
- Later phases (post 2016) would comprise biomass district heating or biomass CHP boilers with locally sourced biomass as the primary fuel supply. These energy centres could be located within proximity to those buildings with anticipated high heat and hot water demand such as the primary and secondary schools, community swimming pool and leisure centre, large supermarket, hotel and health centre.



- The requirement for additional renewable electrical power could be generated through a combination of small-scale building integrated renewables such as photovoltaic cells and small scale roof-mounted wind turbines, although micro wind systems have been proved to underperform in many instances and small scale biomass CHP may also emerge over time as a suitable solution. It is acknowledged that there may be additional benefit to extending a distributed energy network beyond the extents of the Tornagrain Masterplan to support nearby potential customers, particularly those with a significant heating and/or cooling demand such as the proposed Inverness Airport Business Park.
- An Energy Services Company (ESCO) could be established for Tornagrain to facilitate the delivery of a distributed energy network under a design, potentially fund, build operate and maintain agreement. This could be undertaken solely by an expert provider or in partnership with the Local Council or developer.

This strategy is considered a potential solution available to MEDCO and has been devised by WYG Future as initial concept solutions. The following text outlines the key risk and considerations in relation to this strategy.

Key Risks and Considerations

Tornagrain Preliminary Energy Strategy - Site Wide District Heating and Building Integrated Renewables

- Energy centres should ideally be located close to areas of high energy demand to reduce distribution losses and deliver an efficient system.
- Generation of sufficient renewable electricity as biomass boilers provide no renewable electrical output and therefore photovoltaic or microwind is likely to be required post 2016.
- Long term ownership and operation of a distributed energy network by an ESCo or facility manager could be complicated and problematic.
- Multiple energy centres may improve the flexibility of a site wide energy strategy.
- The role of public-wire and private wire electricity connection in delivering low and zero carbon.
- Development is currently under scrutiny and may impact the extent of solutions available.
- Site wide networked strategies are likely to require increased capital expenditure early in the project.



Indicative Carbon Savings and Capital Costs of Strategy A

* Indicative carbon emission reduction and capital cost only derived from original phasing schedule and modified for subsequent final phasing plan. CHP is unlikely to be viable in first years of development. Development is estimated to produce 5,000,000kWh/yr excess heat - this can be used to support low carbon and very low carbon development heat demand (replacing gas fuelled CHP) additional method of heat use or storage must be identified alongside this.

	KgCO2/yr	% Reduction in CO2	Strategy	Capital Cost (£)
2011-2012 - 'Low Carbon' (100 Residential Units and 1,000m² of Non-Residential)				
2007 Baseline Emissions	551,673			
Savings from Energy Efficiency	82,751	15%		Moderate
Savings from Low Carbon and Renewable Energy	193,086	35%	PV, Solar Thermal, Small Scale Wind and Biomass Boilers, first phase district heating to eventually support CHP	£1,500,000.00
Total % Reduction in CO₂		50%	Sub-Total	£1,500,000.00
2013-2016 - 'Very Low Carbon' (244 Residential Units and 2,418m² of Non-Residential)				
2007 Baseline Emissions	1,270,303			
Savings from Energy Efficiency	330,278	26%		High
Savings from Gas CHP District Network	264,196	20%	Assumes 200kWe gas CHP plant	£2,000,000.00
Savings from additional renewable energy	368,387	29%	PV and Small Scale Wind	£4,000,000.00
Total % Reduction in CO₂		75%	Sub-Total	£6,000,000.00
2016-2031 - 'Net Zero-Carbon' (2118 Residential Units and 39,990m² of Non-Residential)				
2007 Baseline Emissions	13,297,030			
Savings from Energy Efficiency	4,919,901	37%		Very High
Savings from Biomass Boiler Heating Network	2,290,495	17%	Biomass boiler heat network	£7,000,000.00
Savings from Small Scale Renewable Power Generation	670,251	6%	PV, Small Scale Wind and other building integrated renewables	£6,500,000.00
Emissions generated by cooking and appliances	5,318,812	40%	Excluded from Calculation	Nil
Total % Reduction in CO₂		100%	Sub-Total	£13,500,000.00
2031-2041+ - 'Total Zero-Carbon' (2,444 Residential Units and 17,314m² of Non-Residential)				
2007 Baseline Emissions	13,988,355			
Savings from Energy Efficiency	5,175,691	37%		Very High
Savings from Biomass Boiler Heating Network*	2,098,253	15%	2MW biomass boiler	£12,900,000.00
Savings from Small Scale Renewable Power Generation	6,714,410	48%	Building Integrated microgeneration	£42,000,000.00
Total % Reduction in CO₂		100%	Sub-Total	£54,900,000.00
Total Indicative Capital Cost				£75,900,000.00

Introduction to Tornagrain Energy Strategy

This study is being carried out by WYG Future on behalf of MEDCO, and looks at the potential development of the site known as Tornagrain, a new sustainable community that forms part of the A96 Corridor strategic expansion area for the Scottish Highlands.

The recent trend to adopt renewable and/or low carbon sources of energy stems from the Kyoto Protocol agreement which came in to force in 2005 and subsequent national climate change goals which aim to reduce carbon emissions which includes a target for Scotland to generate 18% of national electricity from renewable sources by 2010 and 40% by 2020.

The development parameters allow an energy strategy to be developed for supplying site wide energy demand recognising and embracing sustainability objectives. This approach recognises the

influential development characteristics of phasing, and a build out programme lasting 30 years, possibly with differing parties developing separate land parcels.

A 'True Zero-Carbon' standard will be adopted in England and Wales for residential development beyond 2016 and non-residential beyond 2019. This is 14 years earlier than the recommended standard outlined in the Sullivan Report and should this be implemented successfully may result in Scottish policy evolving resulting in quicker step changes in standards than that anticipated in this report.

WYG Future recognises that Tornagrain must meet challenging sustainability targets, which in turn should be balanced alongside the major capital cost associated with truly sustainable energy provision, a considered balance must be achieved in developing a robust and suitable energy strategy at Tornagrain.

Table 1: Tornagrain Phased Build Programme and Assumed Carbon Emission Reduction Standards

Year	Residential Units	Non-Residential (m ²)	Anticipated Carbon Reduction Requirement (Residential)	Anticipated Carbon Reduction Requirement (Non-Residential)
2011-2012	100	1,000	Low Carbon (50% Reduction in CO ₂ per annum)	Low Carbon (30% Reduction in CO ₂ per annum)
2013-2016	244	2,418	Very Low Carbon (75% Reduction in CO ₂ per annum)	Very Low Carbon (60% Reduction in CO ₂ per annum)
2016-2031	2,172	39,990	Net Zero Carbon (100% Reduction in CO ₂ per annum)	Net Zero Carbon (100% Reduction in CO ₂ per annum)
Beyond 2031	2,444	17,314	Total Life Zero Carbon (>100% inc appliance load reduction in CO ₂) per annum)	Total Life Zero Carbon (>100% inc appliance load reduction in CO ₂)



Assumptions, Methodology and Report Conditions



Indicative Layout

The phasing and build programme of Tornagrain has had a significant influence on the solutions proposed within this report. The relatively even, but modest volume of housing completed each year results in a steady increase in site wide energy demand. Initial phases of development (pre 2013 and 2016) are anticipated to have a slightly higher space heating demand profile, as improvements in energy efficiency measures beyond 2016 are anticipated to reduce energy demand for heating. Based on this assumption it is anticipated that the delivery of renewable electrical power, rather than heating will form the most challenging aspect of delivering a sustainable whole-life energy strategy for Tornagrain.

This report is produced solely for the benefit of MEDCO for the proposed uses stated and should not be used in a different context without reference to WYG. No liability is accepted for any reference to it by any other party. This report is limited to those aspects reported on, within the scope and limits agreed.

Based upon the background information supplied to WYG Future, annual space heating, cooling hot water and electricity energy consumption has been extrapolated using guides from Building Services Research and Information Association (BSRIA) and the Chartered Institute of Building Services Engineers (CIBSE) and from experience of similar projects. Reliance has been placed on the documents and information supplied to WYG by others but no independent verification of these has been made and no warranty is given on them. No liability is accepted or warranty given in relation to the performance, reliability, standing etc of any products, services, organisations or companies referred to in this report. Opinions and information provided in this report are based on WYG Future using due skill and care in the preparation of the report.

Information on the type of systems investigated has been taken from a variety of sources including manufacturers' technical data, and project experience. Where possible, manufacturer's information has been used; however, this should not be taken as endorsement of a particular product over other potential suppliers. Where specific examples have not been used, robust 'rules of thumb' have been applied. Any costs quoted are for equipment only and all figures given should be taken as purely indicative at this stage and should not be used as the basis of specifying technologies or carrying out detailed design, i.e. this report should be utilised to provide a strategic overview only. Site specific conditions can vary over time and no warranty is given as to the possibility of changes in the market, legislation or in the environment of the site and the surrounding area over time.

Whilst skill and care have been used, no investigative method can eliminate the possibility of obtaining partially imprecise, incomplete or not fully representative information.

In order to compare the systems being investigated on a level playing field, savings in carbon emissions, and capital costs as well as long term ownership, operation and maintenance issues were considered. The advantages and disadvantages of renewable and/or low to zero carbon technologies were discussed and analysed. The potential influence of our assessment and report on other aspects of any development or future planning requires evaluation by other involved parties. The performance of environmental protection measures and of buildings and other structures in relation to acoustics, vibration, noise mitigation and other environmental issues is influenced to a large extent by the degree to which the relevant environmental considerations are incorporated into the final design and specifications and the quality of workmanship and compliance with the specifications on site during construction. WYG accept no liability for issues with performance arising from such factors.



Energy Efficiency

To reduce Tornagrain energy consumption, it will be important for all dwellings and buildings to be as energy efficient as practical. It is anticipated that minimum standards of energy efficiency are to be mandated as part of changing national and local policy. Understanding what standards may be imposed in 2010, 2013, 2016 and beyond is crucial to developing a suitable provisional energy strategy that is capable of meeting the heat and power demands of Tornagrain. The potential for reducing energy demand prior to the inclusion of any low to zero carbon technologies at the design stage is considerable. Optimising energy efficiency is crucial to reducing the burden on renewable technologies to meet required levels of carbon emission reduction.

Table 2 outlines possible building specification standards for residential development to deliver anticipated changes to national and building regulation policy during Tornagrain's 30 year build programme.

Improved energy efficiency specifications result in significant reductions in annual space heating demand suggesting that the need for traditional central heating systems may diminish and that other methods of providing the residual heating demand may become more commonplace, this results in the balance between the different energy requirements being more heavily focused on the electrical appliance and lighting load.

WYG Future has utilised the figures detailed in the table below in the calculation of individual residential dwelling

Table 2: Illustrative Building Specification Standards CLG Building Regulations Energy Efficiency Requirements for New Dwellings and Published 'Zero-Carbon' Home Standards.

Year	Element	Specification
2010–2012	Roof	0.14
	Wall	0.22
	Doors & Windows	0.09
	Thermal Bridging	0.04
	Airtightness	3
2013–2016	Roof	0.08
	Wall	0.10
	Doors & Windows	0.70
	Thermal Bridging	0.02
	Airtightness	2
2016 and Beyond	Roof	0.07
	Wall	0.08
	Doors & Windows	0.60
	Thermal Bridging	0.01
	Airtightness	1

and site wide loads. Benchmark figures from the Building Services Research and Information Association (BSRIA) and The Chartered Institute of Building Services Engineers (CIBSE) have been assumed for consumption by non-residential buildings with staggered improvements in energy efficiency in line with the forecast standards for residential development.

Table 3: Residential energy demand and carbon emission predictions

	kWh/m ² /annum - from utility or grid					kWh/m ² /annum - from all energy sources (including renewables)					KGCO ₂ /m ² /annum				
	Space Heating	Hot Water	Lighting	Appliances & Cooking	Total	Space Heating	Hot Water	Lighting	Appliances & Cooking	Total	Space Heating	Hot Water	Lighting	Appliances & Cooking	Total CO ₂
Building Regulation 2007 Compliant	58	37	21	36	152	58	37	21	36	152	11.1	7.1	8.9	15.2	42.3
Low Carbon (2010-2012)	44	28	16	36	124	44	28	16	36	124	8.4	5.3	6.6	15.2	35.5
Very Low Carbon (2013-2016)	30	20*	11	36	77	30	28	11	36	105	5.8	5.3	4.7	15.2	31
Net Zero Carbon (2016-2030)	0	0	0	36	36	15	20	11	36	82	2.85	3.8	4.7	15.2	26.55 **
Total Life Carbon (2030-2041)	0	0	0	0	0	15	20	11	36	82	2.85	3.8	4.7	15.2	26.55 ***

*Some form of low carbon or renewable energy must be included to deliver very low carbon

**100% offset by renewables (exc appliances)

***100% offset by renewable generation (inc appliances)



Renewable Energy Policy and Sustainable Assessment Standards

Scottish national renewable energy and sustainability policy and frameworks are currently being developed to derive a directed approach in delivering carbon emission reduction in Scotland. The Scottish government has set a target of generating 18% of national electricity from renewable sources by 2010 and 40% by 2020. The introduction of Energy Performance Certificates (EPCs) in 2007 has also increased awareness of the carbon footprint and sustainability of buildings.

On January 29 2008, the Scottish Government published a consultation which set out proposals for a Scottish Climate Change Bill and sought views on options for a Bill; this consultation was closed in April 2008 and is currently under review. Although is anticipated to eventually mandate an 80% reduction in carbon emissions by 2050.

Scotland does not currently have an adopted policy that sets mandatory requirements for reduction in carbon emissions and in the absence of a finalised Scottish Climate Change Policy WYG Future has made reference to the Low Carbon Building Standards Strategy for Scotland document (referred to as the Sullivan Report) produced in 2007. This document sets out a series of recommendations for the Scottish Government in delivering low and zero-carbon residential and non-residential building standards, and has been used to define benchmark standards of anticipated policy changes that are likely to come into force during the development of Tornagrain.

Environmental Assessment Methods

There are established, national and industry recognised standards in assessing the sustainability of both residential and non-residential development. These methods provide an authoritative rating of a building or homes sustainability.

Ecohomes is the assessment method produced by BRE specifically for residential dwellings. It considers the environmental performance against key criteria that includes energy and water. This method has been replaced by the Code for Sustainable Homes in England and Wales from April 2007 which has more stringent assessment criteria, however as yet this standard has not been adopted in Scotland.

BREEAM is the assessment method that considers the sustainable design and servicing of non-domestic buildings. The assessment can be used to rate a range of buildings from Offices to Schools to Hospitals.

Commitment to BREEAM and EcoHome standards can demonstrate Tornagrain's commitment to delivering sustainable and low-carbon standards.

Tornagrain Energy Demand

Based on information supplied to WYG Future by MEDCO about the extents of the site and phasing programme, an estimated site wide annual operational energy demand and CO₂ emission profile for Tornagrain has been established including both residential and non-residential development.

The table below outlines the estimated annual operational energy demand for the anticipated residential and non-residential development of Tornagrain on the basis of the provisional accommodation schedule and anticipated phased building programme at baseline 2007 building regulation compliant standards.

Table 4: Tornagrain Estimated Baseline 2007 Energy Demand Profile

Phase	Year	Status	Number of Residential Units	Estimated Area of Residential Units (m ²)	Non-Residential Units (m ²)	Anticipated Carbon Reduction Target	Baseline 2007 Building Regulation Compliant Scheme		
							Residential		
							Total baseline residential heat and hot water demand	Total baseline residential electrical demand	Total baseline residential energy demand
							kWh/yr	kWh/yr	kWh/yr
1	2010-2012	Low Carbon	100	11,500	1,000	50% reduction in CO ₂ over 2007 standards	1,092,500	655,500	1,748,000
1	2013-2016	Very Low Carbon	244	28,060	2,418	75% reduction in CO ₂ over 2007 standards	2,665,700	1,599,420	4,265,120
2	2016-2021	Net Zero Carbon	507	58,305	1,000	100% reduction in CO ₂ (exc. Appliances)	5,538,975	3,323,385	8,862,360
3	2021-2026	Net Zero Carbon	780	89,700	18,131	100% reduction in CO ₂ (exc. Appliances)	8,521,500	5,112,900	13,634,400
4	2026-2031	Net Zero Carbon	885	101,775	20,859	100% reduction in CO ₂ (exc. Appliances)	9,668,625	5,801,175	15,469,800
5	2031-2036	Total Life Zero Carbon	960	110,400	3,400	100% reduction in CO ₂ (inc. Appliances)	10,488,000	6,292,800	16,780,800
6	2036-2041	Total Life Zero Carbon	1,100	126,500	10,246	100% reduction in CO ₂ (inc. Appliances)	12,017,500	7,210,500	19,228,000
7	2041+	Total Life Zero Carbon	384	44,160	3,668	100% reduction in CO ₂ (inc. Appliances)	4,195,200	2,517,120	6,712,320
Totals	2011-2041	Variable	4,960	570,400	60,722	Variable	54,188,000	32,512,800	86,700,800



	Non-Residential				Combined Totals			
Total Baseline Residential Carbon Emissions	Total baseline non-residential heating, cooling and hot water demand	Total baseline non-residential electrical demand	baseline non-residential energy demand	Total Baseline Non-Residential Carbon Emissions	Total baseline heat and hot water demand	Total baseline electrical demand	Total baseline energy demand	Total Baseline Carbon Emissions
kWh/yr	kWh/yr	kWh/yr	kWh/yr	KgCO ₂ /yr	kWh/yr	kWh/yr	kWh/yr	KgCO ₂ /yr
486,450	245,690	43,120	288,800	65,223	1,338,190	698,620	2,036,810	551,673
1,186,938	174,336	116,839	291,175	83,365	2,840,036	1,716,259	4,556,295	1,270,303
2,466,302	170,790	83,373	847,763	68,300	5,709,765	3,406,758	9,116,523	2,534,602
3,794,310	3,096,593	1,511,636	847,763	1,238,356	11,618,093	6,624,536	18,242,629	5,032,666
4,305,083	3,562,509	1,739,077	847,763	1,424,680	13,231,134	7,540,252	20,771,386	5,729,762
4,669,920	883,048	568,626	1,764,117	412,288	11,371,048	6,861,426	18,232,474	5,082,208
5,350,950	2,661,091	1,713,572	1,764,117	1,242,443	14,678,591	8,924,072	23,602,663	6,593,393
1,867,968	952,653	613,447	1,764,117	444,786	5,147,853	3,130,567	8,278,420	2,312,754
24,127,920	11,746,710	6,389,691	8,415,615	4,979,442	65,934,710	38,902,491	104,837,201	29,107,362



The table below outlines the estimated annual operational energy demand for the anticipated residential and non-residential development of Tornagrain on the basis of the provisional accommodation schedule and anticipated phased

building programme with a phased programme of gradually improving energy efficiency measures in line with anticipated national energy and sustainability policy and building regulation standards

Table 5: Tornagrain Estimated Annual Operational Energy Demand and Carbon Emissions of development built to anticipated increasing sustainability standards

Phase	Year	Status	Number of Residential Units	Estimated Area of Residential Units (m ²)	Non-Residential Units (m ²)	Anticipated Carbon Reduction Target	Baseline 2007 Building Regulation Compliant Scheme		
							Residential		
							Total Forecast Residential Heat and Hot Water Energy Demand following energy efficiency improvements	Total Forecast Residential Electrical Energy Demand following energy efficiency improvements	Total Forecast residential energy demand following energy efficiency improvements
							kWh/yr	kWh/yr	kWh/yr
1	2011-2012	Low Carbon	100	11,500	1,000	50% reduction in CO ₂ over 2007 standards	828,000	598,000	1,426,000
1	2013-2016	Very Low Carbon	244	28,060	2,418	75% reduction in CO ₂ over 2007 standards	1,627,480	1,318,820	2,946,300
2	2016-2021	Net Zero Carbon	507	58,305	1,000	100% reduction in CO ₂ (exc. Appliances)	2,040,675	2,740,335	5,072,535
3	2021-2026	Net Zero Carbon	780	89,700	18,131	100% reduction in CO ₂ (exc. Appliances)	3,139,500	4,215,900	7,803,900
4	2026-2031	Net Zero Carbon	885	101,775	20,859	100% reduction in CO ₂ (exc. Appliances)	3,562,125	4,783,425	8,854,425
5	2031-2036	Total Life Zero Carbon	960	110,400	3,400	100% reduction in CO ₂ (inc. Appliances)	3,864,000	5,188,800	9,604,800
6	2036-2041	Total Life Zero Carbon	1,100	126,500	10,246	100% reduction in CO ₂ (inc. Appliances)	4,427,500	5,945,500	11,005,500
7	2041 +	Total Life Zero Carbon	384	44,160	3,668	100% reduction in CO ₂ (inc. Appliances)	1,545,600	2,075,520	3,841,920
Totals	2011-2041	Variable	4,960	570,400	60,722	Variable	21,034,880	26,866,300	50,555,380

The anticipated increased performance in energy efficiency specification assumed over the lifetime of the Tornafgrain development and in particular reduced demand for space heating is anticipated to deliver an approximate 66% reduction in total carbon emissions over the 30 year build programme when compared to

a development constructed to 2007 baseline building regulation compliant standards. It is assumed that development at Tornafgrain will deliver residential and non-residential construction standards in-line with anticipated changing standards in building regulation standards and national policy.

Non-Residential			Combined Totals			
Forecast non-residential energy demand	Total Forecast Non-Residential Heat and Hot Water Energy Demand following energy efficiency improvements	Total Forecast Non-Residential Electrical Energy Demand following energy efficiency improvements	Total Forecast Combined Heat and Hot Water Energy Demand following energy efficiency improvements	Total Forecast Combined Electrical Energy Demand following energy efficiency improvements	Total Forecast Energy Demand following energy efficiency improvements	Forecast Carbon Emissions following energy efficiency improvements
kWh/yr	kWh/yr	kWh/yr	kWh/yr	kWh/yr	kWh/yr	
235,372	200,237	35,143	1,028,237	633,143	1,661,372	467,617
237,308	120,292	80,619	1,747,772	1,399,439	3,183,608	933,835
690,927	97,350	47,523	2,138,025	2,787,858	5,763,462	1,605,004
690,927	1,765,058	861,632	4,904,558	5,077,532	8,494,827	3,115,205
690,927	2,030,630	991,274	5,592,755	5,774,699	9,545,352	3,545,744
1,437,755	503,337	324,117	4,367,337	5,512,917	11,042,555	3,200,348
1,437,755	1,516,822	976,736	5,944,322	6,922,236	12,443,255	4,105,983
1,437,755	543,012	349,665	2,088,612	2,425,185	5,279,675	1,439,666
6,858,726	6,776,739	3,666,709	27,811,619	30,533,009	57,414,106	18,413,401

Building Integrated Low to Zero Carbon or Renewable Technologies

One potential energy strategy at Tornagrain includes low to zero carbon and renewable technology integrated on individual dwellings or buildings as part of the buildings energy services, each building integrated technology represents specific cost, planning, design and long term ownership and operation implications.

Small Scale Wind Turbines

One option is to install small 'domestic' wind turbines on the roofs of buildings. This would have significant aesthetic impacts and potential structural constraints. These turbines would also give rise to vibrational noise which would need to be dampened and the electrical energy produced would still be subject to fluctuation.

The development of small-scale roof-mounted wind turbines is relatively new, with a limited number of turbines at the post-development stage and in mass production. This means that prices for installed turbines is currently still quite high, but lower than roof mounted photovoltaic arrays and therefore certainly worthy of consideration.

Increasingly energy wholesalers are providing mechanisms for the purchase of any excess electricity supported by small scale micro generation systems to ensure any excess renewable electricity is not wasted but provides an economic return for small scale generators. An agreement with an electricity supply company is needed to facilitate this.



Small Scale Wind Turbines Technology Summary

- Manufacturer: Renewable Devices (Swift Rooftop Wind Energy System)
- Approximate cost per 1.5kW unit = £4,000
- Annual power supplied = 1,200kWh

Wind turbines should not be designed to provide the sole electrical supply as even in areas with suitably high wind speeds there would be occasions when the speeds would not be sufficient to accommodate electrical demand. Connection to the incumbent electricity distribution network operator (DNO) is therefore a requirement to meet peak daily demand and backup in the event of system failure or maintenance. Export mechanisms can facilitate the sale of any excess electricity generated back to the grid network.

Table 6: Summary of small scale wind turbines potential contributions to reducing annual energy demand

Small Scale Wind Installation (1.5kW) No of Units	Electrical Output (kWh/yr)	Percentage of total site electrical demand	Annual CO ₂ Saved (KgCO ₂)	Percentage Reduction in Total Site CO ₂ Emissions	Cost (£)
2,390	2,868,413	10%	1,233,417	7%	9,560,000
11,951	14,342,066	50%	6,167,088	36%	47,806,884
23,903	28,684,132	100%	12,334,177	71%	95,613,775



Photovoltaic Panels

Photovoltaics (PV) convert the light energy from the sun into electricity and could be considered for generating electricity for the site. PV modules are rated by the power they generate – kilowatt hour peak (kWp). Types of PV fall into categories which include:

- Monocrystalline PV
- Polycrystalline PV
- Thin film (amorphous) PV
- Hybrid PV

Hybrid film/crystalline mixed PV units are the most electrically efficient. This type of module can be fixed to a sub framework mounted above the roof covering. Equally, this system is easily retro-fitted to existing roofs and incorporated above new roofs. The advantage of this type of system is that the equipment minimizes the visual impact and acts as additional weather and UV radiation protection to the roof covering.

The roof areas for the site will have a percentage of a southerly aspect. Detailed development proposals should consider the inclusion of PV where it is considered a possible renewable energy generation solution. It is therefore possible to fit the PV on the south facing side of the roof areas to generate electricity for the site.

It is assumed that any PV installation is likely to use monocrystalline silicon photovoltaics as these tend to be the most efficient and would take up the minimum roof area. A total roof area available for PV of circa 50m² is assumed for residential units; although much less could be used (non-residential units may be capable of accommodating significantly larger installations). Sufficient provision must be made to allow access to the roofs if necessary and any other roof-mounted plant and solar thermal technologies. Consideration could be given to using a metal sheeting product that can offer a more discrete building integration with roof cladding; however capital costs are currently significantly higher when compared to the fitting of modular units above the roof in a standard frame. This would require more careful consideration during the development of detailed design proposals. It is assumed that a PV system could be connected to the buildings'



electrical distribution system. The performance of PV systems is susceptible to shading issues, which can reduce system efficiencies. The Tornagrain development should carefully consider the impact of poor shading where any form a solar technology is considered for integration.

Each kWp of PV capacity installed generates on average approximately 840 kWh/yr electricity. One kWp PV equates to an area of approximately 8-9 m²

Clearly, PV alone cannot provide all the electricity for Tornagrain. PV becomes more attractive as the cost of grid-supplied electricity increases, thus over its 25 year or more lifetime, may prove to be financially viable. PV requires only nominal maintenance, usually once a year to provide a visual and electrical check. There have been cases of premature inverter failure, though instances have been declining





in recent years. The sheer cost of photovoltaics and their very poor financial payback makes this technology less attractive when compared to other renewable technologies. However, the Tornagrain site's significant demand for renewable electricity and likely constraints to including large scale wind turbines means systems are likely to be included in delivering a suitable energy strategy for Tornagrain and there may be hidden value through a striking visual statement regarding renewable energy technologies. It is concluded that photovoltaics are technically feasible for this development, though costly, it is recommended that consideration be given to inclusion alongside other technologies at this stage.

Photovoltaic Technology Summary

- Area required for 1 kWp = 9 m² / 2.5kWp = 20m²
- Average annual output = 840 kWh / 2122kWh
- Approximate equipment cost per 2.5kW monocrystalline installation = £6,500

- Can obtain savings on roof cladding by fitting integral panels
- High capital costs with long payback periods (60 – 100 years).
- Efficiency dependent on weather so designed to only 50% of load
- Panels need replacing approximately every 35 years

Costs quoted below are installed system costs based on previous projects and include purchase and installation of panels and integration with the building's electrical system. It does not account for a decrease in capital costs over time or potential savings from bulk purchasing.

The Table below provides a summary of the assessment giving the potential savings in carbon emissions.

It is estimated that a 20m² of panel could reduce a 2010 specification residential dwellings annual carbon emissions by up to 32%.

Table 7: Summary of photovoltaic systems potential contributions to reducing annual energy demand

Area of PV panel (m ²)	Electrical Output (kWh/yr)	Percentage of total site electrical demand	Annual CO ₂ saved (KgCO ₂)	Percentage reduction in total site CO ₂ Emissions
27,032	2,868,132	10%	1,233,297	7%
135,174	14,342,066	50%	6,167,088	36%
251,499	28,684,132	100%	12,334,177	71%

Solar Thermal Heating Systems

Solar thermal systems have been used for many years at a small scale, and recently have been developed for a much wider market with pressurised systems. They convert solar radiation into hot water. All systems use solar collectors and a liquid handling unit to transfer heat to the load, generally via a storage tank. The liquid handling unit includes the pump(s) (used to circulate the working fluid from the collectors to the storage tank) and control and safety equipment. When properly designed, solar water heaters can work when the outside temperature is well below freezing and they are also protected from overheating on hot, sunny days.

Solar thermal systems perform three basic operations:

- Collection: Solar radiation is "captured" by a solar collector;
- Transfer: Circulating fluids transfer this energy to a storage tank; circulation can be natural (thermosiphon systems) or forced, using a circulator (low-head pump)
- Storage: Hot water is stored until it is needed at a later time in a plant room, or on the roof in the case of a thermosiphon system.

There is a hot water demand throughout the site, generated by the primarily residential nature of development, however this it is not very high when compared to electrical demand.





The orientation of the roofs should lend themselves to solar thermal technologies, either as a building integrated solution on south-facing roofs or on the top of any residential blocks. As the roof-area is considered unlikely to be limited, it is suggested that flat-plate panels could be used. These could be connected to a hot water storage facility and provide a pre-heat for conventional gas-fired boilers.

The total hot water demand for a typical dwelling is in the order of 2,000 kWh per annum and solar thermal systems can be connected to wet or dry manifold systems depending on water quality and can be accommodated in most domestic buildings. A medium-scale domestic installation is 5m² with an effective output of up to 2,000kWh per annum, however anticipated solar irradiation in Tornagrain may result in decreased performance and an output closer to 1,200kWh per annum equal to 60% of the estimated annual demand of a typical dwelling. The cost impact of implementation is anticipated at being in the region of £2,500 per installed unit, depending on issues such as how the panels are attached to the roof. Approximately 5m² of roof per panel with a pitched roof in the range (-/+30%) of south facing is required. Adequately sized storage tank(s) for hot water are required; it is assumed that 100 litres of storage would be required for every panel installed. Based a typical 5m² installation delivering 1,200kWh per annum, solar thermal panels installed on all single tenancy dwellings would reduce total site carbon emissions by around 7%.

The average payback time for the investment in solar thermal is approximately 10 years with no grant aid. There would be a reduction in the total energy demand for the site, but capacity cannot be reduced owing to the intermittent nature of solar irradiance. The total cost would be subject to consultation with an appropriate supplier at the detailed design stage. It is recommended that Solar thermal is feasible for this development, but should be noted that if a site wide CHP scheme is introduced then the technology may not be compatible.

Solar air heating cladding may also be considered for commercial industrial buildings as a cost effective alternative method of providing heated ventilation.

Solar Thermal System Summary

- Panel Size = 3m² (5m² installed)
- Average heat output per panel per year = 1,200kWh
- Approximate equipment cost per panel = £2,500
- Can obtain savings on roof cladding by fitting integral panels
- Efficiency dependent on weather so designed to meet percentage of load
- Established technology

Table 8: Summary of solar thermal hot water systems potential contributions to reducing annual energy demand

Area of Solar Thermal Panel (m ²)	No of Units	Hot Water/ Heating Output (kWh/yr)	Annual CO ₂ Saved (KgCO ₂)	Percentage reduction in Total Site CO ₂ Emissions	Total Hot Water Storage (litres)
2,500	500	600,000	114,000	0.65%	50,000
5,000	1000	1,200,000	228,000	1.3%	100,000
16,330	3266	3,919,200	744,648	4.3%	326,600
24,800	4960	5,952,000	1,130,880	6.5%	496,000



Gas Micro CHP Generation (Domestic)

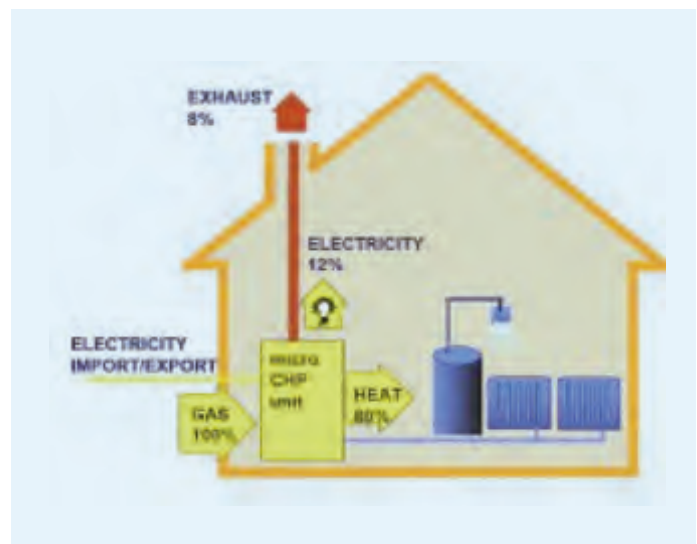
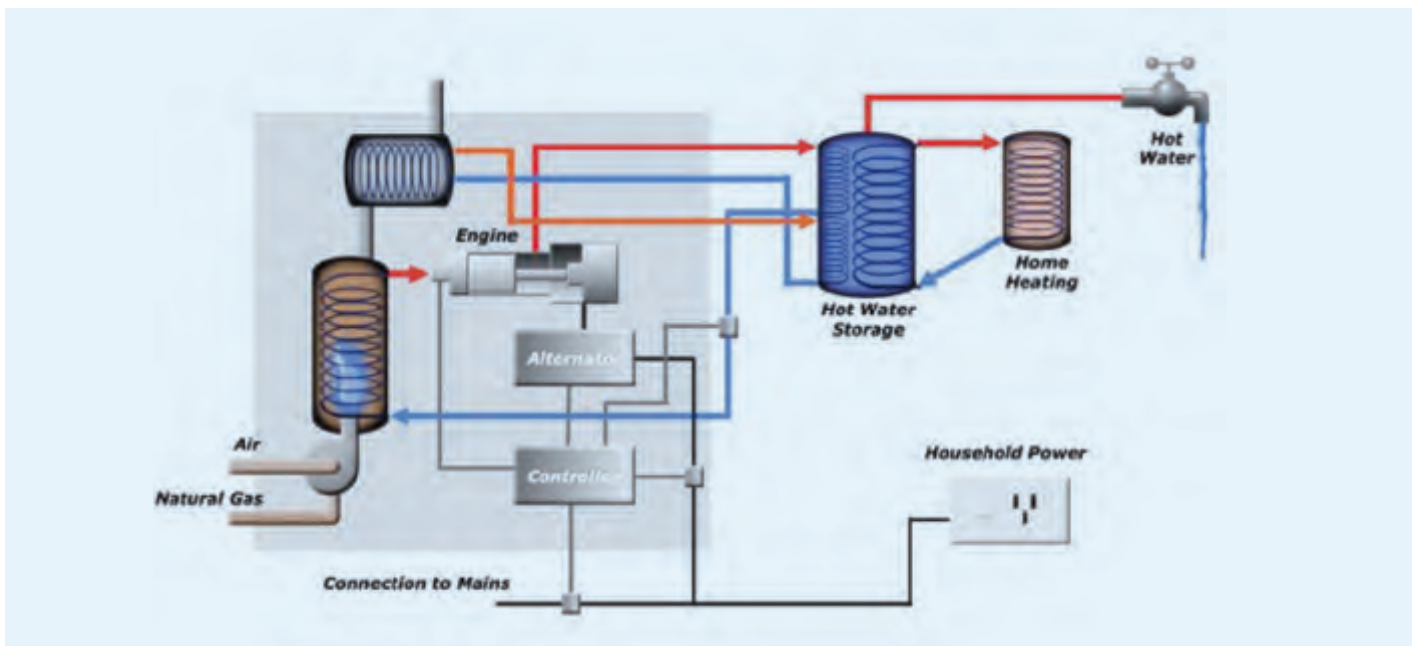
This is a relatively new technology to the UK and not yet widely available. WYG consider that adopting this technology at Tornagrain would require a significant maturing of the market with significant developments in Micro CHP technology. Should grants or co-funding be made available then this might be worth further consideration.

The Baxi Ecogen is a micro CHP unit designed for domestic use in the same way as a traditional gas boiler and was unveiled on March 5 2008. This unit is capable of providing up to 24kW of thermal output for space heating and hot water as well as 1kW of electricity per hour performing at 90% efficiency in terms of fuel

used to generate heat and electricity. The unit is approximately the size of a standard boiler, and it is claimed to be virtually noise free.

Testing of the Baxi micro-CHP unit has been underway in homes for over a year, providing domestic heat and hot water as well as generating electricity. Initial trials and testing has (according to Baxi) indicated savings of 1,000 to 2,000KG of carbon dioxide per annum. Baxi also claim the Ecogen micro CHP unit will be commercially available from early 2009.

Large scale integration is considered unlikely to be suitable even during the initial 'low-carbon' phases of development at Tornagrain, however installation on a small number of residential units, perhaps on those less suitable for connection to a larger CHP distributed energy scheme, may be considered.





Small Scale Biomass Heating

As with large bio-fuel installations (see section 8.3) small-scale domestic applications are usually fuelled by wood pellets, wood chips or alternatively wood logs can be used.

Generally, there are two ways of using biomass to heat a domestic property:

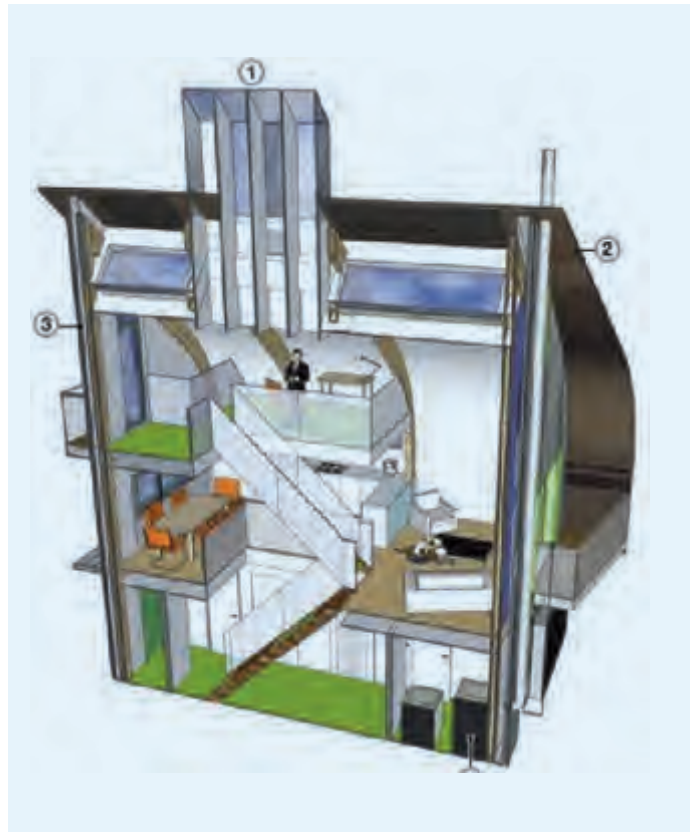
1. Standalone stoves providing space heating for a single room. These can be fuelled by logs or pellets but only pellets are suitable for automatic feed. Generally they are 5-7 kW in output, and some models can be fitted with a back boiler to provide water heating
2. Increasingly, boilers are connected to central heating and hot water systems. These are suitable for pellets, logs or chips, and are generally >15 kW. There are many domestic log, wood chip and wood pellet burning central heating boilers available. Log boilers must be loaded by hand and may be unsuitable for some situations. Automatic pellet and wood chip systems can be more expensive. Many boilers will dual fire both wood chips and pellets, although the wood chip boilers need larger hoppers to provide the same time interval between refuelling.

It is important for homes to have storage space for the fuel, appropriate access to the boiler for loading and access to sufficient locally sourced fuel supply.

The vent material must be specifically designed for wood fuel appliances and there must be sufficient air movement for proper operation of the stove. Chimneys can be fitted with a lined flue. Installation of domestic biomass boilers must comply with all safety and building regulations.

Stand alone room heaters generally cost £2,000 to £4,000 installed. With full heating and hot water systems costing >£8,000.

Many current zero-carbon homes utilise domestic biomass boilers in delivering space heating alongside other heat and power generating renewables such as solar thermal hot water system, photovoltaic technology and small scale wind turbines.





Heat Pumps

Heat pumps extract thermal energy from a variety of renewable sources, including the air, earth or water, and upgrade it to a higher, more useful temperature. If the heat source for the system is the air then it is known as an Air Source Heat Pump (ASHP).

Ground Source Heat Pumps (GSHP) have a relatively constant Co-efficient of Performance (CoP) whereas air source heat pumps have a CoP that declines with air temperature. GSHPs are considered to be quieter and have a longer life than air source pumps since they are not externally exposed to the natural elements.

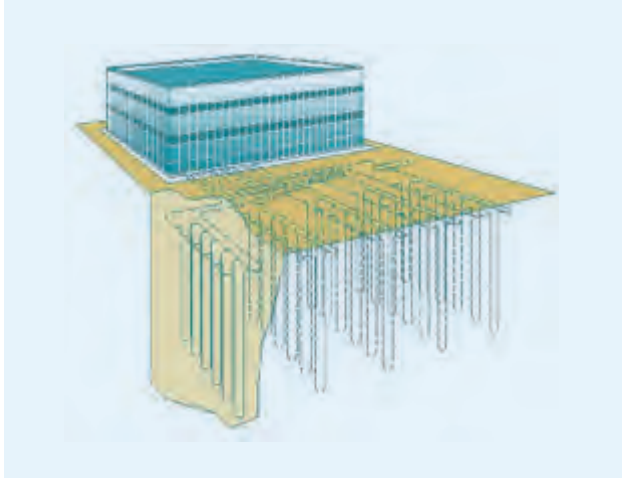
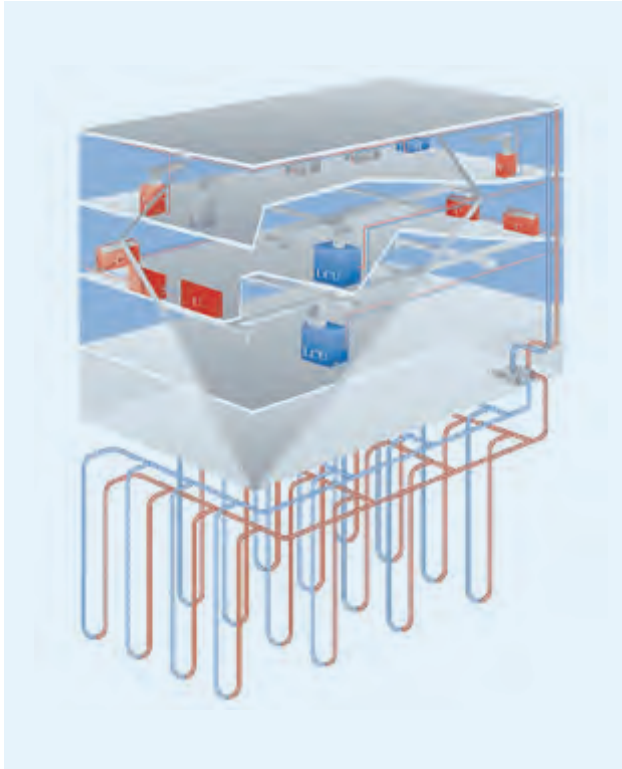
Further analysis is required before it can be determined whether sufficient land area would be available for a horizontal loop system, and this would include analysis as to the suitability of ground conditions given the extent of existing hard standing. Further electrically operated pumps are not zero-carbon unless powered from a further renewable power generation source.

Assuming that the ground conditions are suitable, a GSHP system could be a technically feasible building integrated solution. The water temperatures that can be delivered by a ground source heat pump system (35-55°C) are lower than those typically used in radiator systems (70-80°C). Underfloor heating operates at lower temperatures and it is able to be used in combination with ground source heat pumps without any adaptation and should achieve high efficiencies. Equally, the use of oversized radiators could be employed if so desired.

The efficacy of ground source heat abstraction depends on the thermal conductivity of the surrounding soil; as a general rule the "wetter" the soil, the greater the thermal efficiency. It is also more effective in low-grade heat applications like under floor heating instead of radiators. Naturally, the suitability of any ground source heating system is highly dependant on the ground conditions and a full site survey needs to be undertaken before considering such technologies in further detail.

Vertical boreholes are very expensive and are normally only considered where there is no option to use horizontal loops. A solution might be vary the scale of hard landscaping surrounding the development and to sink vertical boreholes into the soil before any new hard landscaping is in place, or on the periphery of the site. The pipe work could then be brought up at specific locations, possibly adjacent to foundation support structures and up into the buildings above. Again, combining a GSHP system with renewable electricity generating technologies i.e. photovoltaics, can be used to complement GSHP and deliver zero carbon electricity required by the heat pump.

The consideration of any surface water strategy including the utilisation of onsite attenuation and drainage systems could impact upon the land area available for a GSHP horizontal loop system.





Ground Source Heat Pump Technology Summary

- Manufacturer: Kensa
- Approximate equipment cost per kW = £1,000, + cost of connection (price depends on number and size of compressors)
- Typical length of piping required per kW = 10 m (horizontal loop) and 22 m (vertical bore)
- Efficiency (CoP) taken to be 4 (2.5 for ASHP)
- Typically designed to meet only 50%-80% of heating load
- Can be horizontal slinkies or vertical bore holes (vertical drilling is expensive)
- Need to first carry out site analysis to determine ground conditions
- Work very well with underfloor heating as the heat supplied and heat output is low grade
- Heat pumps can be powered by Photovoltaics to be 100% 'green'

Air Source Heat Pump Technology Summary

- Manufacturer: RM Solar Ltd
- Approximate equipment cost per 12kW unit: £7,000
- Efficiency (CoP) taken to be 2.5
- Typically designed to meet only 50%-80% of heating load
- Work very well with non conventional low grade heating systems
- Heat pumps can be powered by Photovoltaics to be 100% 'green'

Given the anticipated reduced space heating demand at Tornagrain over the build programme and the need for electrical power to drive ground and air heat pumps, it is considered unlikely that a large site-wide heat pump strategy will be suitable for the site. However, small scale systems linked to renewable power generation or in the initial low-carbon phase (2010-2012) of development could deliver carbon savings. The significant demand envisioned for electrical power in supporting lighting and appliance loads means that heat pumps may not be best suited to delivering 'zero-carbon' development beyond 2016.

Green Energy Supply

All major providers of electricity are currently developing national renewable power resources such as offshore wind farms and/or are purchasing power from such sources. The power is sold to customers as Green Energy. Tornagrain could potentially arrange for a Green Energy Option to be available to all units initially on handover.

Experience for suppliers of such energy is that a high percentage of homeowners stay with the same provider and so a significant but unquantifiable amount of electrical power long-term would be from renewable sources. Although this is not recognised as an onsite renewable contribution or acknowledged in any BREEAM or EcoHomes Assessment, it is felt that it could significantly improve the whole-life sustainability of the development by potentially influencing the energy sources utilised by the end-users.



ScottishPower





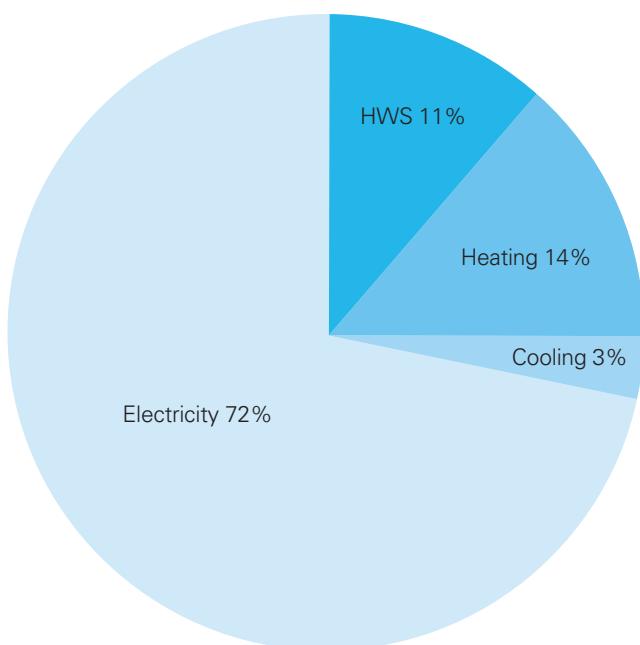
District Low to Zero Carbon or Renewable Technologies

To deliver a sustainable community with a reduced carbon footprint adopting a site wide energy strategy can enable economies of scale to be embraced thereby balancing of different energy demand profiles. A site wide strategy could include a site wide power or heating distribution network or a combination of both.

In common with all developments of this type the predominant source of the emissions is from the electrical usage on site. Although there is some cooling demand for non-residential development in Tornagrain, in overall development terms it is anticipated to be modest. Equally the amount of heating required is likely to decrease dramatically beyond 2016 as improvements in building energy efficiency significantly reduces the extent to which heat is needed for space heating.

A site wide strategy that produces electricity is likely to be crucial delivering 'zero-carbon' development beyond 2016 and 'total zero-carbon' development beyond 2020. Potential additional energy demand within proximity to Tornagrain such as Inverness Airport, Inverness Airport Business Park (IABP) and the Norbord Factory may be able to form part of a larger distributed energy strategy, enabling an increased base load for the sizing of any CHP or other installation. However, the arrangements for connection, ownership and operation could become complex. It is identified as an option for future consideration only at this stage.

Tornagrain Estimated Annual CO₂ Emissions



Large Scale Wind Turbines

Our evaluation of large scale wind turbines to generate electricity for the Tornagrain site has shown it to be generally inappropriate due to proximity to Inverness Airport. Whilst wind conditions in the North of Scotland may be favourable it is understood that MEDCO do not perceive large wind installations as appropriate for inclusion at Tornagrain.

Large turbines can cause problems of noise and visual pollution and are difficult to obtain planning approval for. In addition, low wind speeds can impact upon system efficiency in producing sufficient electricity to justify the capital cost. Wind energy technology can be unreliable as it is dependent on weather conditions, however in terms of assessing contributions to reduce annual carbon emissions under established calculation methods, the annual energy generated is assessed as relatively constant and connectivity to the local distribution network will be a given.

Generally the most limiting factor when identifying suitable sites for wind turbines is whether there is sufficient wind. Additionally, the inclusion of suitable buffer zones is required around any residential development. A buffer zone of 300m between a large turbine and the nearest dwelling is recommended as at this distance the noise levels from a large turbine are generally regarded as acceptable to mitigate against.

Shadow flicker and visual impact are regarded as site specific, and subject to specific detailed proposals. It is the responsibility of a developer proposing inclusion of a large turbine to demonstrate the impact of shadow flicker and for the local planning authority to decide upon whether it presents an issue to existing or proposed development.

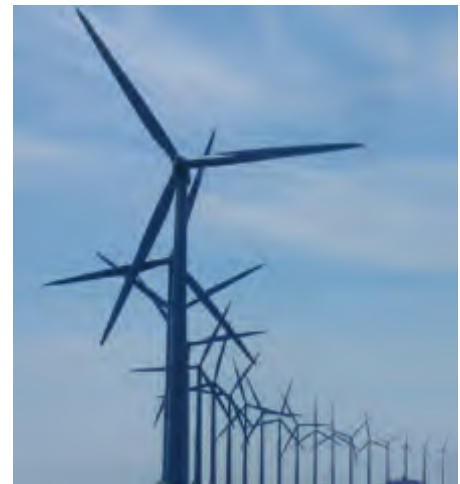
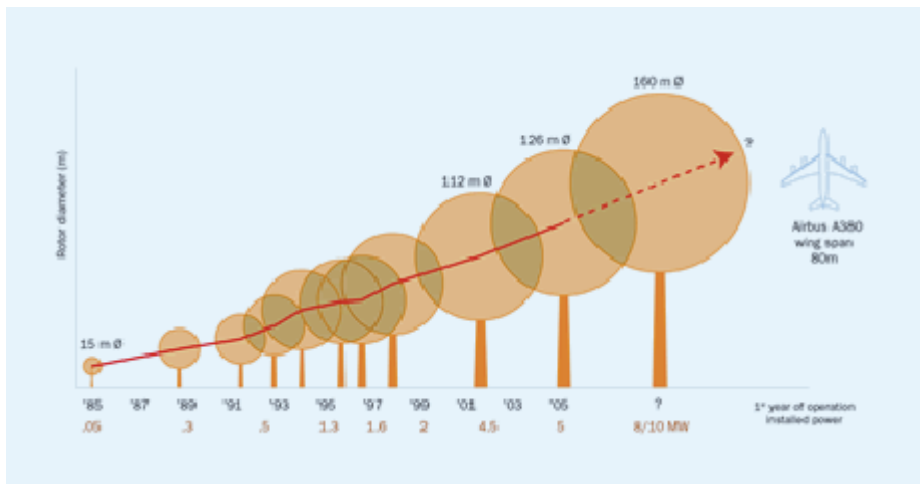
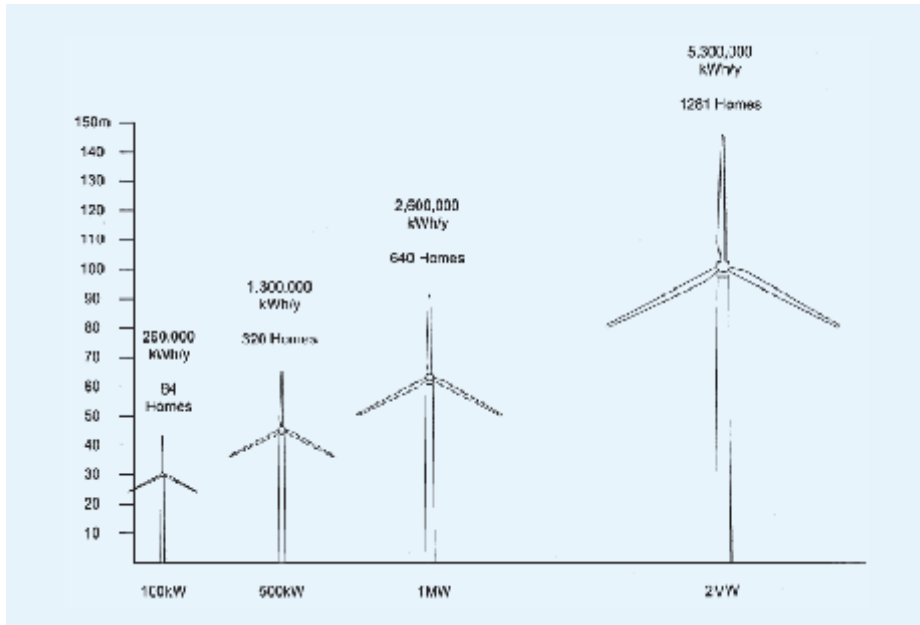
Wind turbines currently present issues for both the Civil Aviation Authority and Ministry of Defence. The most import issues are whether turbines present an obstacle for aircraft or whether they would be picked up on radar. Potential air traffic constraints and communication masts are location specific and are considered to represent a significant constraint at the Tornagrain site (Inverness Airport is within close proximity to the site); however a detailed assessment would be required to fully determine the impact and location of large scale wind turbines at specific locations within the site boundary. This is typically undertaken by a developer proposing any large turbine installation.

A large scale wind installation is unlikely to be suited to Tornagrain in the delivery of renewable energy to the development, however this option should not be fully discounted given the significant demand for renewable electricity anticipated at Tornagrain and an offsite installation connected via private –wire may provide an alternative option.





Figure 2: Approximate size and outputs of large scale wind turbines



District Heating and Power with CHP

A key method to enhancing the energy-efficiency of a development is to embrace economies of scale, where possible. Thus, centralised heating plant can be preferable to individual heating systems, especially where there is a constant demand for heat and hot water throughout the year. A centralised system is therefore well-suited to residential units, leisure facilities, health centres, schools and hotels. Whenever a centralised system is considered suitable, the CO₂ saving which can be gained from employing Combined Heat and Power (CHP) should be considered.

CHP is usually applicable when it is used to provide heat and electricity for over 5,000 hours a year and is therefore ideally suited to a demand profile which is predictable and relatively constant.

At Tornagrain, a single gas fed CHP plant installation could be sized to meet a proportion of the heating, cooling and hot water requirement of development (2010-2016). A 700kWe CHP (either single unit or modular installation) would deliver 5,600,000 kWh of heat per annum; this would reduce the CO₂ emissions from the site by 22% (excluding distribution losses). Such a system is anticipated to meet 70% of heating demand, slightly higher than ideal and suitable demand for this additional heat would likely need to be identified offsite. After considering the improvements achieved through energy efficiency compared to baseline 2007 standards, this is assumed to be closer to 50%. In this strategy high efficiency gas fired boiler plant would provide the additional heat required for the development and support peak demand and maintenance periods.

The chart opposite demonstrates the current understanding of micro to large CHP and the benefits of the various schemes this has been reproduced as a guide to CHP sizes.

Table 9: Gas CHP carbon emission reduction calculator

Gas Combined Heat and Power CO ₂ Reduction Calculator			
Input Data	Annual heating demand 2010-2013	4,764,317	kWh/yr
	Annual Electrical demand 2010-2013	3,331,423	kWh/yr
	Typical model CHP		
	Rated heat output of CHP	1120	kW
	Rated electrical output of CHP	700	kW
	rated fuel input	2374	kW
	Distribution losses	10%	
	CHP efficiency	80%	
	Annual Operational Hours	5,000	Hrs
Heat	Annual heating demand met by CHP	5,600,000	kWh/yr
	Percentage of heating demand met by CHP	118%	max 60%
Electricity	Net Electricity generated	3,500,000	
	CO ₂ conversion factor for grid electricity being displaced	0.568	
	CO ₂ saved by CHP electricity generation	1,988,000	kWh/yr
Fuel Input	Annual fuel input (gas)	11,870,000	Gas
	CO ₂ factor for the input fuel	0.194	
	CO ₂ emissions by CHP due to fuel consumed	2,302,780	kgCO ₂ /yr
Conventional Heating System Being Replaced	Seasonal efficiency of conventional gas boiler	86%	
	Annual fuel consumption of conventional gas boiler	6,384,000	kWh/yr
	CO ₂ factor for input fuel to conventional gas boiler	0.194	Gas
	CO ₂ emissions by conventional gasboiler	1,238,496	kgCO ₂ /yr
Carbon Savings	Annual Carbon Savings from CHP	923,716	kgCO ₂ /yr



KW/MW Range	Scale	Application	Benefit	
			Consumer	Economy
1KW-3KW	Micro	Domestic use	<ul style="list-style-type: none"> • Additional costs recovered. • Electricity generation and export potential. • £100-£125 per annum primary energy saving. • Individual engaged in reducing national emissions 	<ul style="list-style-type: none"> • Potential for less demand on national grid and on power stations. • Reduction in CO₂ emissions 1 tonne per annum per customer. • UK could be leaders in this technology. Increase in production would mean employment opportunities.
3-50KW	Micro/Small	Primary schools, guest houses, pubs, restaurants and small offices	See above	See above
50KW-5MW	Small Scale and Mid Scale (Packaged units)	Public sector buildings, Community Energy Schemes, leisure centres, hotels, commercial, light industrial, hospitals and universities and small blocks of flats	<ul style="list-style-type: none"> • Primary energy and CO₂ savings guaranteed • Computer controlled and remotely monitored • High efficiency and high reliability • Predictable and controllable • Short build and installation times (5 months from order) proven technology 	<ul style="list-style-type: none"> • Primary energy savings will enhance UK security of supply. • Delivers on UK governments Environmental and CHP targets. • The use of non conventional fuels (Biofuels) creates tangible benefits to other industries (i.e. farming) • Use in public buildings would demonstrate government's commitment to these targets.
5MW plus	Large	Industrial application and large Industrial District Energy Schemes	<ul style="list-style-type: none"> • Reduction in the use of primary fuels. • Reducing cost of generation which can be passed onto the consumer. • Reductions of carbon emissions and other products of combustion. • Host organisations reduce their environmental footprint and "green" business image. • Can be designed to continue to operate and serve essential loads during an interruption to mains power supplies. • Strengthens and reinforces the network. 	
1-10MW	Large	Food industry		
5-100MW	Large Scale	Chemical industry		
<100MW	Large	Refineries and power stations with district heating/cooling		





As a result of the build programme, a single CHP and district heating scheme on part of the site may not be commercially viable until the development reaches a significant load, before this the energy lost in distributing the heat around the system could result in the system being unviable.

WYG Future understands the significant importance of sustainability at Tornagrain and development is assumed to aspire to deliver significant targets for carbon reduction and the building of low carbon developments, supporting an eventual move to zero carbon. A robust low-carbon infrastructure at Tornagrain could allow businesses and homes to connect and, in time, deliver a zero carbon energy source.

The location of any energy centre is more about the practicality of its location, fuel supply and availability of infrastructure for both gas and electricity to support the needs of an energy centre. Although a valid argument can be made for the establishment of one major energy centre operating at a variable electrical output in line with development phasing, the practicality of a single energy centre would be dependent on the ability to source a practical site that does not negatively impact on the town and has the capability to adapt to variable energy needs and fuel sources.

It is believed that a large scale CHP energy centre may be viable within five to ten years (as development load increases) but a satellite solution may prove more practical for securing a significant low carbon energy base and infrastructure in the short term. In fact, it could be argued the satellite CHP stations could help secure the long term future for the larger energy centre, and improve the viability in the early stages of network development.

Many new large developments and urban expansions sites have failed to establish town or city wide heat and power schemes due to the lack of awareness and support from initial and future phase developers and landowners and the time it takes to establish a base heating network from which to expand. Multiple energy centres in early stages, with later linking to a larger network can present a significant opportunity to overcome these barriers. This approach has been used in many other developments across the UK.

There is significant evidence that a multi-fuel energy centre which can adapt its primary fuel source may be best suited to meeting market forces while maintaining security of supply. The practicality of utilising multiple satellite energy centres can allow the development of distributed energy infrastructure around Tornagrain and can secure customers in the short term whilst building the low carbon heat and electricity network for now and the future.

A multiple energy centre system may be considered with each centre strategically located centrally or in close proximity to areas or buildings of high heat demand. Advantages of a multiple energy centre system are:

- Security of supply; twin systems offer a degree of redundancy.
- Reduced mains losses; locating the energy centre near to the load reduces losses, and increases the viability of the scheme.
- Closer match to the phasing; a large single centre is likely to be located at the edge of the site in the latter phases of the project.

With all schemes, time is a major factor and certainly for the CHP and the energy distribution network it has to be available at an appropriate time for the developers to utilise the network and benefit from the opportunity to connect to an existing infrastructure. Therefore, for Tornagrain any energy distribution needs to be established early in development and sized for future loads including importing and exporting energy. Once low-carbon energy infrastructure is in place land parcel developers are able to connect and take the cleaner, more sustainable and efficiently available energy for their homes and buildings.

A site wide distributed energy network enables future changes in fuel supply markets to be quickly adapted too. Any gas CHP plant installed could potentially be replaced at the end of its lifetime (15-years) by linking to a carbon neutral installation, further reducing the carbon footprint of initial low-carbon and very low carbon phases of development at Tornagrain.



District Strategy 2016 and Beyond – Delivering ‘Zero-Carbon’

To completely achieve ‘Net Zero Carbon’ and ‘Total Zero Carbon’ standards at Tornagrain, from an energy perspective, all the energy used on the development has to be generated from renewable sources.

Currently the long term availability of bio fuels is not fully understood. This study proposes that any energy centre or centres are initially designed and planned as gas fired, but suitable space is allowed for the future installation of biomass heating plant or biomass CHP. For example, in Strategy B (see page 4) gas fired CHP engines could be established to support initial development phases, and these could then be changed to a large biomass CHP plant utilising locally source biomass as primary fuel supply. Suitable space would need to be allowed for the future installation of any biomass CHP plant including consideration of the requirements of fuel supply delivery and storage, chimney (>23m) and associated emissions.

Any Biomass CHP plant is likely to be sized to a base thermal load and be matched to the changing demand of each development phase. A secure and locally available source of fuel is crucial to the success of any biomass scheme and WYG Future understands that MEDCO manages over 4050Ha of commercial forestry; this extensive wood resource within proximity to Tornagrain highlights the potential suitability of a biomass solution.

‘Net Zero Carbon’ (2016-2030) and ‘Total Zero-Carbon’ (2030-2041)

To achieve the ‘Net Zero Carbon’ standard, which is the provision of all energy from renewable sources, except that used for cooking or appliances and the ‘Total Zero-Carbon’ standard, which is the provision of all energy from renewable sources, including that used for cooking or appliances, a bio fuel fired system is likely to be required.

The following tables gives indicative volumes of bio-fuel material required each year for a 1.8MW boiler, including volume of storage and deliveries required for three fuel types. The storage estimates are based on 2 weeks reserve of fuel. Guaranteed supplies of fuel could reduce this storage, and it is assumed that Tornagrain could potentially benefit from establishing a robust biomass fuel supply framework. In multiple energy centre scenarios, it is possible to split energy production such that storage and delivery requirements are spread across a number of energy centre locations.

Table 10: Indicative bio-fuel storage and supply requirements

Biomass Storage and Fuel Supply - Wood Chip		
Biomass Unit	1,800	kW
Running Hours	5,000	hrs/annum
Output	9,000,000	kWhrs/annum
Fuel Source	Wood Chip	
Quantity of fuel	2,813	Tonnes/annum
Volume of Fuel	11,254	m ³ /annum
Storage required	1,608	m ³ /annum
Deliveries (based on 14m ³ truck)	804	per annum

Biomass Storage and Fuel Supply - Wood Pellet		
Biomass Unit	1,800	kW
Running Hours	5,000	hrs/annum
Output	9,000,000	kWhrs/annum
Fuel Source	Wood Pellet	
Quantity of fuel	1,800	Tonnes/annum
Volume of Fuel	2,770	m ³ /annum
Storage required	391	m ³ /annum
Deliveries (based on 14m ³ truck)	198	per annum

Biomass Storage and Fuel Supply - Bio Diesel		
Biomass Unit	1,800	kW
Running Hours	5,000	Hrs/annum
Output	9,000,000	kWhrs/annum
Fuel Source	Bio Diesel*	
Quantity of fuel	772	Tonnes/annum
Volume of Fuel	857	m ³ /annum
Storage required	121	m ³ /annum
Deliveries (based on 14m ³ truck)	61	per annum

* Note 123m³ of biodiesel is assumed as 115,000 litres

Biomass CHP as part of a large plant and distribution network or multiple smaller biomass heating installations could provide solutions to delivering zero-carbon standards beyond 2016. The table below indicates potential carbon savings achieved by a large biomass CHP installation.

Table 11: Biomass CHP carbon emission reduction calculator

Bio Fuel Combined Heat and Power CO₂ Reduction Calculator			
Input Data	Annual heating demand 2010-2013	18,175,063	kWh/yr
	Annual Electrical demand 2010-2013	19,727,263	kWh/yr
	Typical model CHP		
	Rated heat output of CHP	4000	kW
	Rated electrical output of CHP	1000	kW
	rated fuel input	3392	kW
	CHP efficiency	80%	
	Annual Operational Hours	5,000	Hrs
Heat	Annual heating demand met by CHP	20,000,000	kWh/yr
	Percentage of heating demand met by CHP	110%	
Electricity	Net Electricity generated	5,000,000	kWh/yr
	CO ₂ conversion factor for grid electricity being displaced	0.568	
	CO ₂ saved by CHP electricity generation	2,840,000	kgCO ₂ /yr
Fuel Input	Annual fuel input (gas)	16,960,000	Biomass
	CO ₂ factor for the input fuel	0.025	kWh/yr
	CO ₂ emissions by CHP due to fuel consumed	424,000	kgCO ₂ /yr
Conventional Heating System Being Replaced	Seasonal efficiency of conventional gas boiler	86%	kWh/yr
	Annual fuel consumption of conventional gas boiler	22,800,000	kWh/yr
	CO ₂ factor for input fuel to conventional gas boiler	0.194	Gas
	CO ₂ emissions by conventional gasboiler	4,423,200	kgCO ₂ /yr
Carbon Savings	Annual Carbon Savings from CHP	6,839,200	kgCO₂/yr

This calculation indicates that a 1MWe biomass CHP installation could reduce annual carbon emissions by 6,839,200kgCO₂/yr, equal to a 50% reduction on the estimated total emissions from 2016 to 2041, and as demand from appliances and cooking is assumed to account for almost 50% of carbon emissions from 2016 and beyond, it could potentially deliver a 'net-zero carbon' solution. However, such an installation could generate a significant heat surplus and this heat would have to be utilised productively to ensure CHP is good quality and energy is not wasted. Connection to the

Inverness Airport Business Park (IABP) or in place of earlier gas CHP output could provide potential solutions to utilise this excess heat.

It is likely that additional renewable electrical energy will be required to meet total-zero-carbon standards anticipated beyond 2030, unless improvements in CHP power to heat output ratios or advances in thermal storage allow a larger unit capable of meeting all of Tornagrain's annual power demand to be installed (>3MWe) without the dumping of surplus heat and wasting of energy.

Conclusions

Renewable and low to zero carbon energy technologies in tandem with improved energy efficiency measures help to reduce annual carbon emissions by reducing the need for energy consumed in space heating, cooling, lighting, etc. and thereby also reducing annual operational energy costs.

Anticipated change to Scottish energy policy and building regulation standards indicates that the 30 year build programme for Tornagrain will require a phased energy strategy that delivers a sustainable low-carbon community, eventually progressing to deliver 'Net Zero-Carbon' and 'Total Zero Carbon' standards. However, it should be noted that changes in policy and standards from those anticipated in this report may significantly affect the extent to which low to zero carbon and renewable technologies are integrated at Tornagrain.

Networked site wide strategies or, alternatively, individual building integrated solutions may be adopted, each with different benefits and drawbacks. In this section, three energy scenarios are considered. At this stage a site wide distributed heating network complemented by CHP and building integrated renewables in the preferred low to zero carbon energy strategy for Tornagrain. Alternative solutions based wholly on building integrated renewables and large scale biomass CHP has also been considered.

Large-scale wind technology is likely to be unsuitable due to the proximity of the site to Inverness Airport and the often negative public perception of such installations, although the sites significant demand for renewable electricity means this should not be wholly discounted at this stage.

A site wide distributed heat or heat and power network including the integration of Combined Heat & Power is considered for this site as a potentially suitable technology; however the modest space heating demand of later development phases, particularly beyond 2016, means any CHP installation must be carefully designed and sized to ensure that excessive quantities of surplus heat is not generated. Implementation of a biomass system is considered due to the availability of a locally sourced suitable fuel supply within close proximity of the site. More detailed analysis may present the opportunity to establish dedicated energy crops adjacent to the site specifically for supplying heating or power plant. Large biomass CHP plant can be visually intrusive and careful consideration needs to its location, the building infrastructure, fuel supply and storage as required for biomass generation would require careful consideration.

Traditional gas and electrical infrastructure would have to be installed to provide a percentage of demand for Tornagrain, particularly in initial phases of development and to support systems failure as the site move towards 'zero-carbon' standards beyond 2016. This infrastructure will also be required to meet daily peak demand periods and provide additional security.

Small scale wind turbines, solar thermal system, heat pumps, photovoltaics and biomass boilers could potentially be integrated at Tornagrain either during initial phases to supplement a site wide strategy or as part of a wholly building integrated solution.

Key Considerations

Taking all the findings of this report into consideration, WYG Future has determined a series of key points for consideration, in delivering a suitable energy strategy for Tornagrain.

- Development should include as much low energy design as possible to reduced total annual operational energy demand. This should at least be in accordance with anticipated changes to mandated building regulation standards.
- The potential of a site-wide distributed heat and/or power network can result in improved efficiency in comparison to individual building heating systems and allows economies of scale to be embraced as well as flexibility to adapt networks to changing fuel supplies. However, the cash flow implications can sometimes be prohibitive.
- Distributed energy networks can present complex long term ownership and operation issues and will normally require the involvement of an expert provider. Should Tornagrain be developed as discreet land parcels by individual developers, then the coordination and implications of a site wide strategy may require complex agreement and negotiation.
- The local availability of biomass means Tornagrain is well positioned to deliver 'zero-carbon' standards. Biomass CHP or biomass heating plant connected to a distributed network is considered a potentially suitable strategy for the delivery of zero-carbon standards beyond 2016.
- Tornagrain's estimated energy profile indicates an increased demand for electricity as improvements in design and energy efficiency are anticipated to reduce the need for space heating. The delivery of sufficient low to zero carbon and renewable electricity is likely to be challenging, and it is recommended that the role of large scale wind should not be completely discounted at this stage.
- Building integrated renewables present a variety of options for inclusion at Tornagrain and a combination of different technologies, either supplementing a site wide strategy or acting as part of a wholly building integrated solution, may be considered.



Proposed Energy Strategy for Tornagrain

Tornagrain's preliminary energy strategy for delivering a sustainable new community is based on delivering a phased reduction in annual carbon emissions in line with anticipated changes in national energy policy and building regulation standards in Scotland.

A phased programme of energy efficiency measures is proposed, implemented to reduce total site energy demand in line with anticipated national carbon reduction policy and building regulation standards (this will reduce the burden on renewable technologies).

Compliance with established environmental assessment standards (BREEAM/EcoHomes) can demonstrate the sustainability and carbon footprint of development and enables verification by an independent accredited body, highlighting Tornagrain's commitment to sustainability. It is recommended that Tornagrain considers committing to a phased standard that gradually improves over time.

It should be possible to achieve a phased reduction in CO₂ from onsite renewable energy generation at Tornagrain, through to the integration of an appropriate low to zero carbon and renewable energy strategy based on a site-wide district heating network with multiple energy centres located strategically across the site to minimise distribution losses. Initially, this is likely to be in the form of a series of small independent networks eventually becoming interconnected over the course of the build programme to provide greater efficiency and security.

Prior to 2016, networks would be led by modular gas fired CHP engines sized to meet a progressively increasing base thermal load in line with the build programme of Tornagrain, delivering sufficient reduction (40-50%) in carbon emissions to meet anticipated requirements. However, some building integrated renewables (such as photovoltaic cells and or micro-wind turbines) might be included to further reduce annual carbon emissions (certainly post 2013).

Later phases (post 2016) would comprise biomass district heating energy boilers with locally sourced biomass as the primary fuel supply. These energy centres could be located within proximity to those buildings with anticipated high heat and hot water demand such as the primary and secondary schools, community swimming pool and leisure centre, large supermarket, hotel and health centre.

The connection of a site-wide strategy can be affected by the development of individual discreet land parcels by different developers and the need to install infrastructure early in the development.

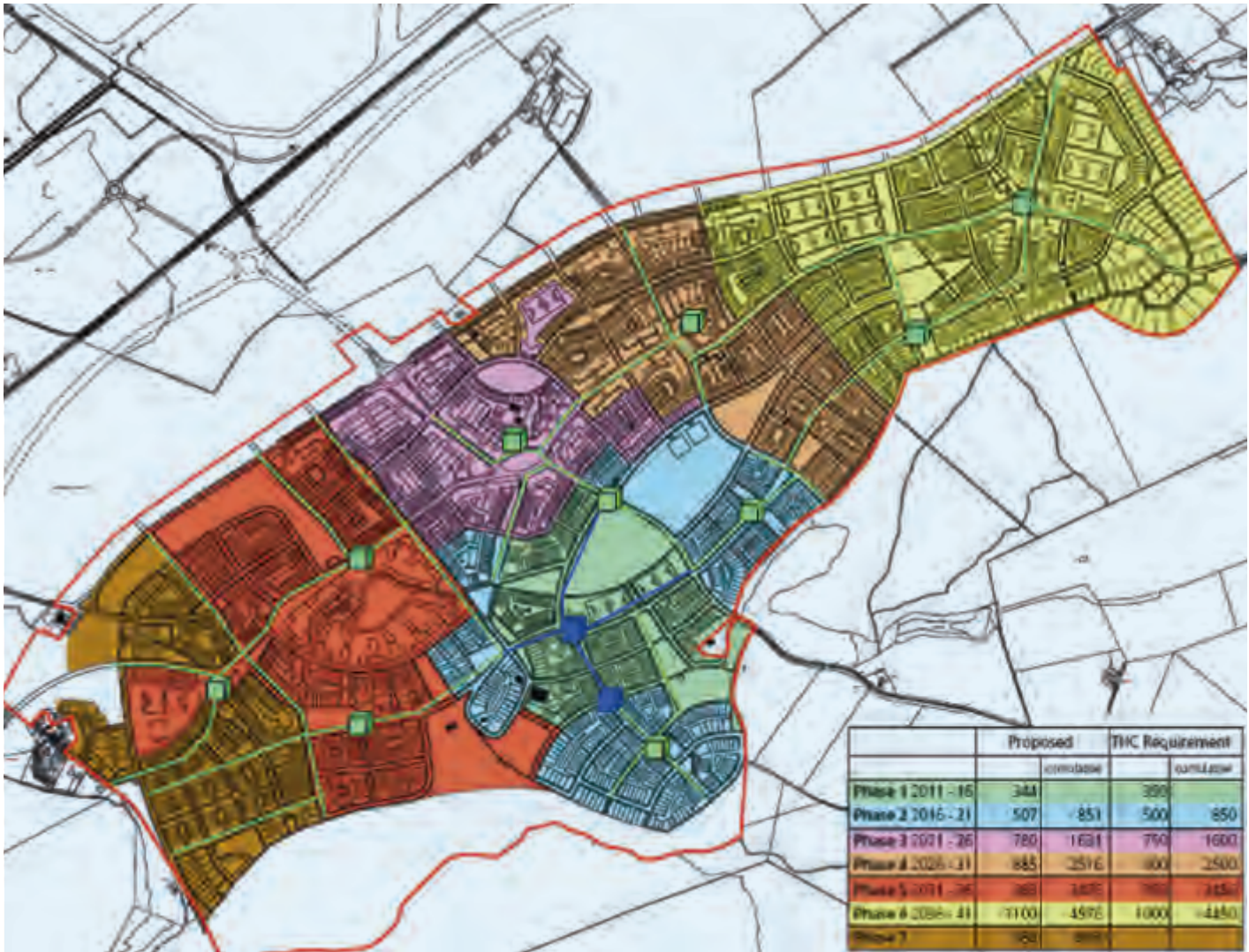
The requirement for additional renewable electrical power could be generated through a combination of small-scale building integrated renewables such as photovoltaic cells and small-scale wind turbines.



It is acknowledged that there may be additional benefit to extending a distributed energy network beyond the extent of the Tornagrain to support nearby potential customers, particularly those with a significant heating and/or cooling demand such as the proposed Inverness Airport Business Park.

An Energy Services Company (ESCo) could be established for Tornagrain to facilitate the delivery of a distributed energy network under a design, potentially fund, build operate and maintain agreement. This could be undertaken solely by an expert provider or in partnership with the Local Council or developer.



Appendix A: Tornagrain Preferred Energy Strategy – Site Wide District Heating Map

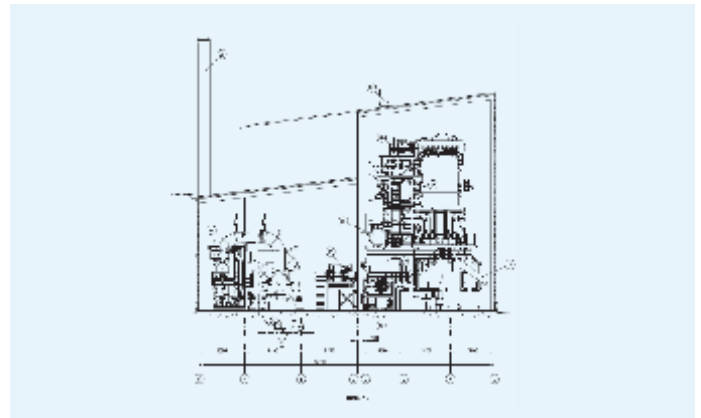


-  Gas CHP Energy Centres
-  Biomass Boiler Energy Centres

Appendix B: Alternative Strategy – Site Wide Distributed Energy including Biomass CHP

A site wide distributed energy network with a single large biomass CHP energy centre located strategically in Tornagrain.

- Prior to 2016 phase 1 would include a heat and power distribution network led by a modular gas CHP engine, sized to meet a progressively increasing base thermal load of Phase 1 in line with the build programme of Tornagrain (same as Strategy A although plant and equipment would require locating at a suitable location for significant expansion over time).
- Post 2016 a large scale biomass CHP plant to deliver renewable heat and power to Tornagrain as part of an extended distributed heat and power network and utilising the availability of locally sourced fuel supply.
- It is acknowledged that the use of biomass CHP may result in a less than ideal match between energy supply and demand with a potential significant heat surplus given the estimated reduced heating demand due to improvements in energy efficiency post 2016. However Biomass CHP could replace the gas fired CHP established in Phase 1 and therefore utilise any excess heat (further reducing the whole life carbon footprint of Tornagrain). Advances in thermal energy storage and the potential of BTES and UTES systems may present a method of minimising any surplus heat generation and additional building integrated renewable power generation especially if surplus heat cannot be utilised beyond Tornagrain.
- Extending a biomass CHP distributed energy network beyond the extents of the Tornagrain masterplan to support nearby potential customers such as the proposed Inverness Airport Business Park is strongly recommended.
- An Energy Services Company (ESCO) could be established for Tornagrain to facilitate the delivery of a distributed energy network under a design, fund, build operate and maintain agreement; this could be undertaken solely by an expert provider or in partnership with the Local Council.



The indicative capital cost of Strategy A and B will be affected by the cost of distributed heat and power networks – this may increase capital cost significantly.

Key Considerations

- A single large energy centre requires substantial land area and suitable location, but can enable expansion and modification.
- Large biomass CHP plant would be distinct in appearance; this may there have planning issues.
- Delivery of fuel for a 2MWe installation is estimated to require >200 truck deliveries per annum.
- A shortfall in renewable electricity is a risk as current biomass CHP outputs could result in a significant heat surplus given anticipated reduced space heating requirements beyond 2016.
- The negotiation and procurement of a site wide distribution scheme could be complex and require a greater initial investment in heat and power infrastructure.

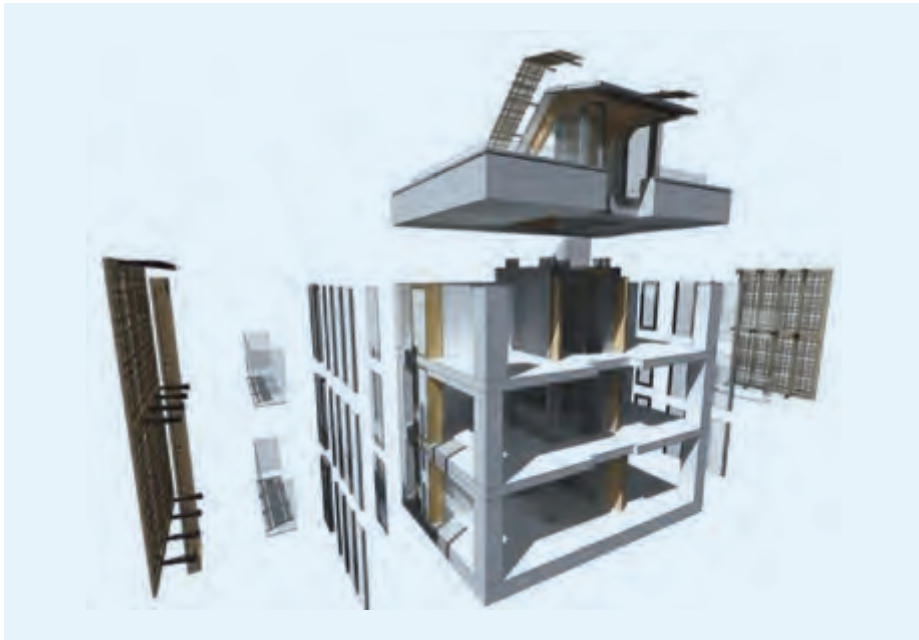
Appendix C: Alternative Strategy – Wholly Building Integrated Renewables

A building integrated renewable solution, focusing on renewable generation on a building by building basis to meet anticipated low-carbon and renewable energy generation obligations.

- Pre 2016, development could include solar thermal technologies to meet the low-carbon standard on residential dwellings (additional renewable generation is anticipated for development beyond 2013) high heat and power demand sites (primary school and leisure centre) could be supported by individual gas or biofuel fed micro-CHP units or domestic biomass boilers
- Post 2016, development could include individual combination solar thermal, photovoltaic and small scale biomass heating systems, integrated as part of the individual building services with each individual building and home designed, constructed and serviced to 'zero-carbon' standards.

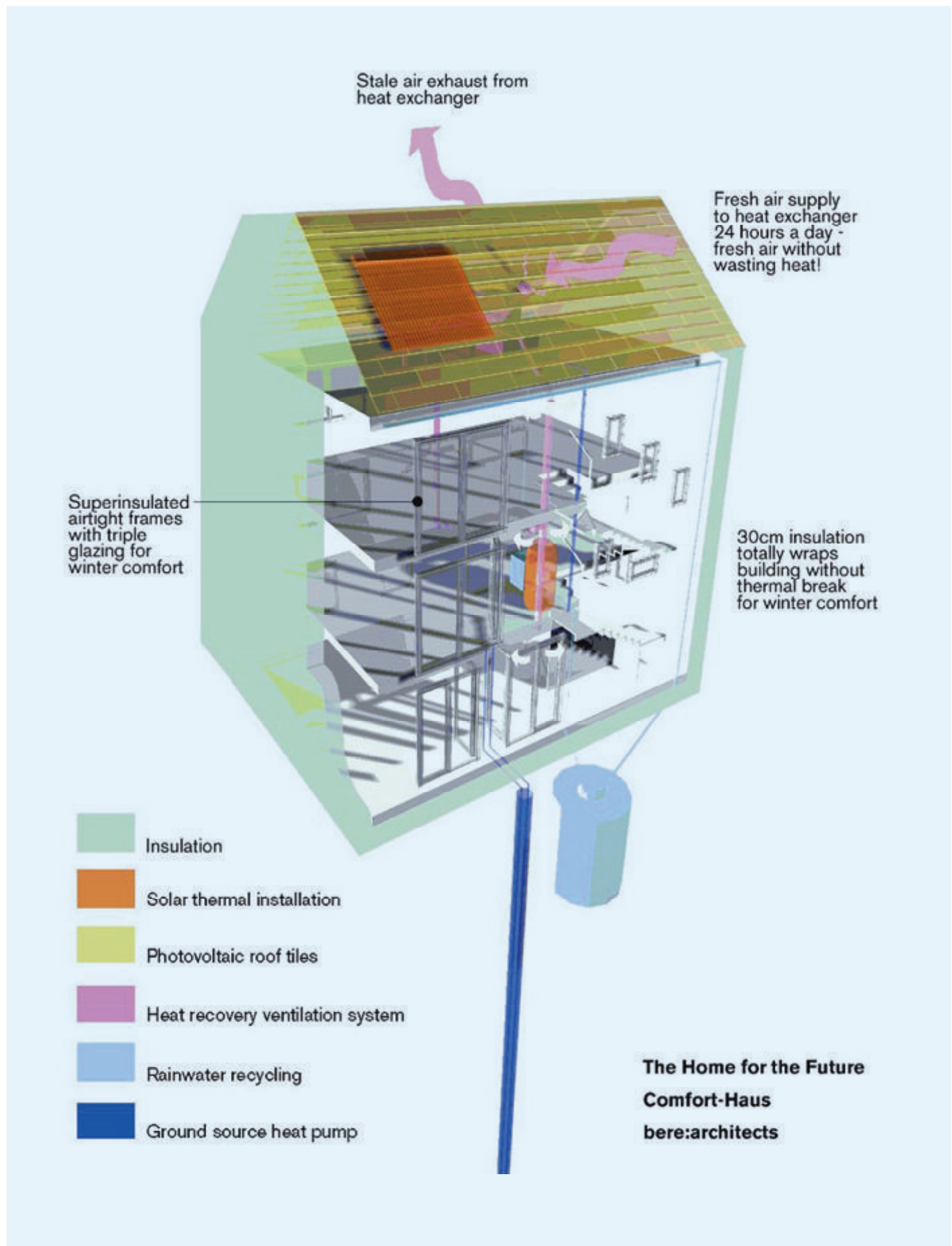
Key Considerations

- Individual building and dwelling energy systems reduces the need for investment in non-traditional heating and power networks.
- All systems are likely to still require connection to traditional grid network to ensure security of supply and buildings and homes are likely to be less readily able to adapt to changes in fuel supply markets than communal systems.
- Building integrated systems require less initial capital investment in infrastructure other than that required to procure traditional electricity and gas connections, but overall capital expenditure could potentially be significantly greater.
- Renewable energy solutions can have a distinct aesthetic impact upon building design.





Appendix D: Alternative Strategy C – Example Building Integrated Renewable 'Zero-Carbon' Home



Appendix E: Checklist of Low Energy Design Considerations

A. Building-related

1. What are the anticipated activities and uses within the proposed buildings on the sites?
2. Will the internal areas be arranged to minimise energy requirements?
3. Will the construction and insulation to roofs, walls and floors be optimised for the heating system and occupancy anticipated?
4. Will new windows be selected to provide the optimum compromise between day lighting and heat loss?
5. Will appropriate steps be taken to minimise air infiltration through the building fabric?

B. Heating System

1. Has the right fuel been chosen, e.g. natural gas, bio diesel, biomass?
2. Will the heating plant be in the best positions to avoid heat losses in pipes, ideally centrally located or near largest load?
3. Has the cost-effectiveness of more efficient plant and equipment been considered?
4. What are the most appropriate control systems, e.g. weather compensation, optimised start?

C. Hot and Cold Water

1. Has the most appropriate means of generating hot water, including heat recovery from a space heat producing process when practicable, been considered?
2. What are the most appropriate controls, particularly at the point of water use, e.g. leak detection?

D. Pipe work / Ductwork

1. Will the pipe runs in the building be minimised and sized correctly by assessing energy efficiency or alternative system configurations to ensure efficient fan and pump operation?
2. Will the pipes be sized correctly for the flow of fluid that will be anticipated in the system?
3. Will the pipe insulation thickness and material be the most appropriate for the application?

E. Lighting

1. Will the optimum lighting requirements be designed for?
2. Will the most efficient type of lamp suitable for the application be selected?
3. Will the most efficient type of luminaire suitable for the application be chosen?
4. Will an appropriate maintenance schedule be included and determined?
5. Will the switching arrangement match the operating needs of the building and the availability of daylight?
6. Will the best use of manual and automatic lighting controls be considered?

F. Ventilation

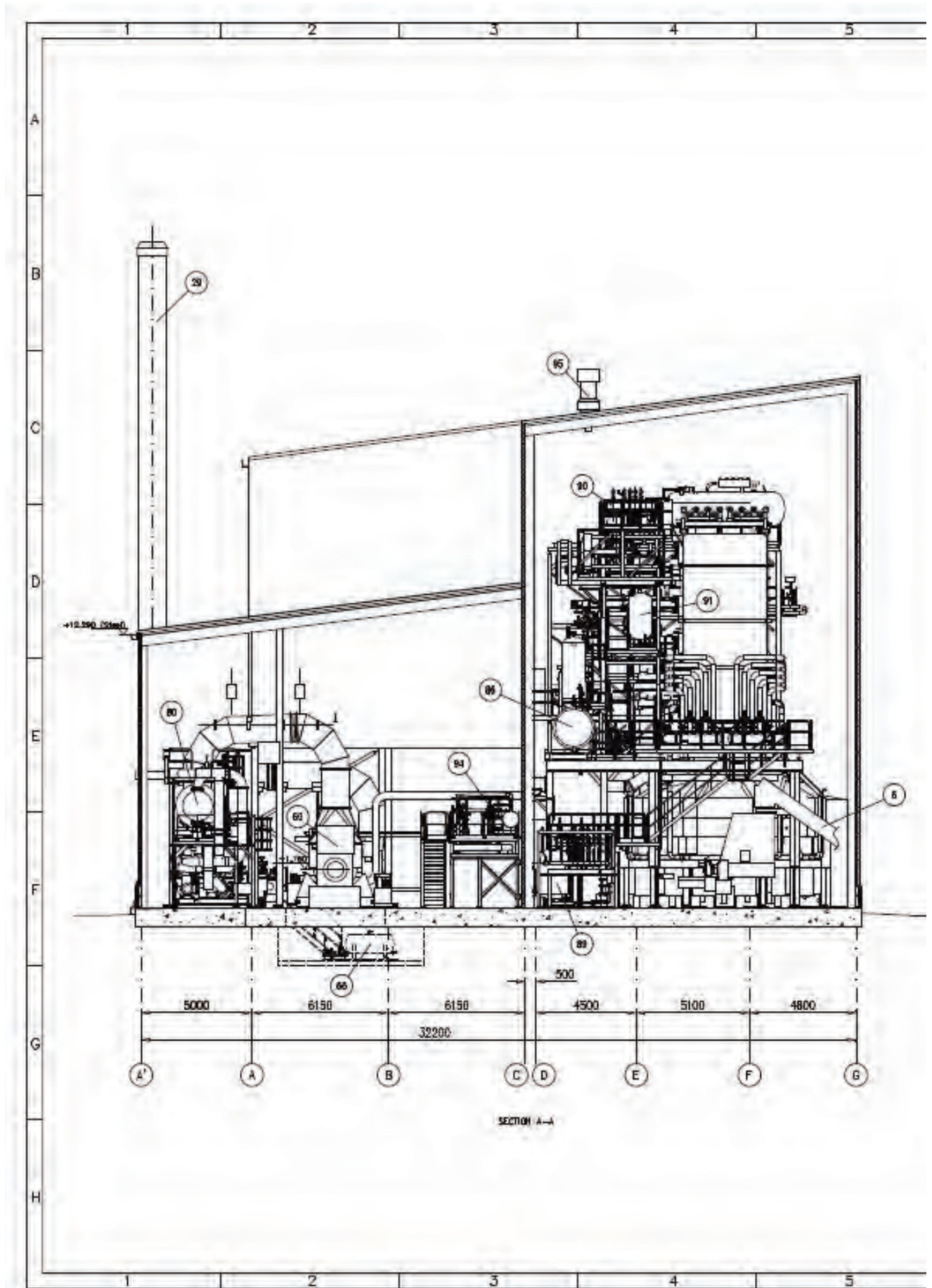
1. Will controlled ventilation systems be designed to provide the required air change rates with minimum energy use, i.e. minimal mechanical ventilation or purely natural ventilation while using variable speed fans and heat recovery?
2. Will appropriate control techniques be adopted, i.e. demand control?

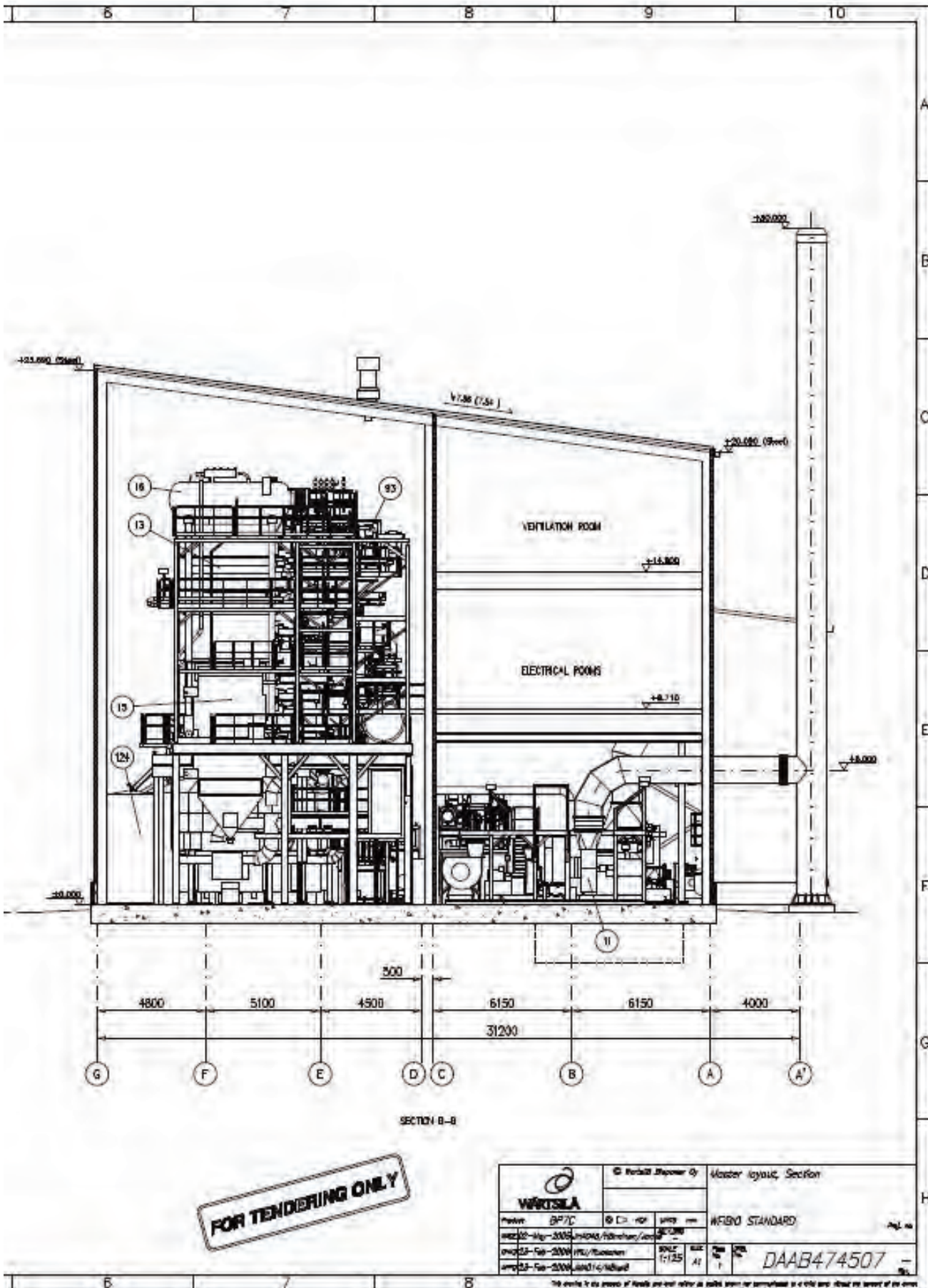
G. Cooling and Refrigeration and Process Mechanical Load

1. Understanding any anticipated cooling requirements for the building such as air conditioning for the offices.
2. Is the mechanical load allowed in terms of electricity consumption accurate enough?
3. If CHP is utilised there will be surplus heat in summer which could be used for 'free' cooling by means of a process called trigeneration which works like a refrigerant cycle to produce cooling.

Note: This list is not exhaustive but if given due consideration and appropriate application should reduce the energy requirements for a development. Assuming that some or all of the above criteria are considered, there will be an energy saving for the site. At this stage, however, it is not easy to estimate the savings which could be realised as this would be based upon gross assumptions; this process should be carried out and continually refined throughout the detailed design process.

Appendix F: Large Biomass CHP Plant (2MWe)











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