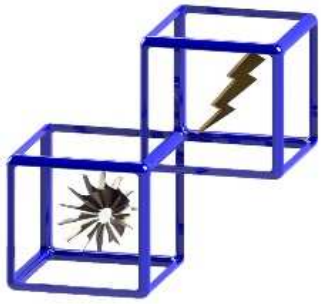
Hot Air Turbine systems

by

Bluebox Energy Ltd



Hot Air Turbine modules turning heat into:

50-330 kWe electric power

Heat to Electrical

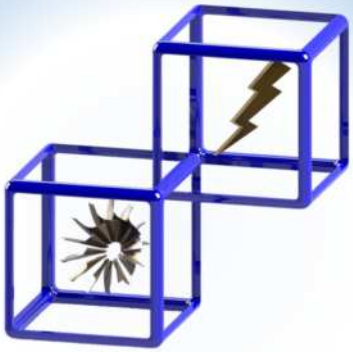
Net Efficiency

10 –18%

Parasitic losses <3%

Low capital cost

Outlet temperatures match high temp heating & absorption chilling



Suits Biomass, RDF, sewage sludge and other waste combustion

Industry proven components

Bluebox Energy

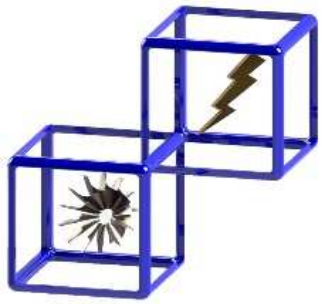
Unmanned, 24/7 operation

Compatible with ORC in combined cycle for high efficency applications

www.bluebox.energy

Bluebox-50	Bluebox-80	Bluebox-110	Bluebox-220	Bluebox-330

Hot Air Turbine systems by Bluebox Energy Ltd



How hot air turbines work...

Ambient air is compressed and fed into a heat exchanger

Air is heated using a waste-wood combustor, waste incinerator or concentrated solar source

Air is first expanded through a turbine to produce power for the compressor

Air is then expanded through a power turbine to produce electric power

⇒ An inverter is used to convert the power produced by power turbine to grid quality AC

⇒ The discharge air from the power turbine is used to dry the fuel, produce hot water /

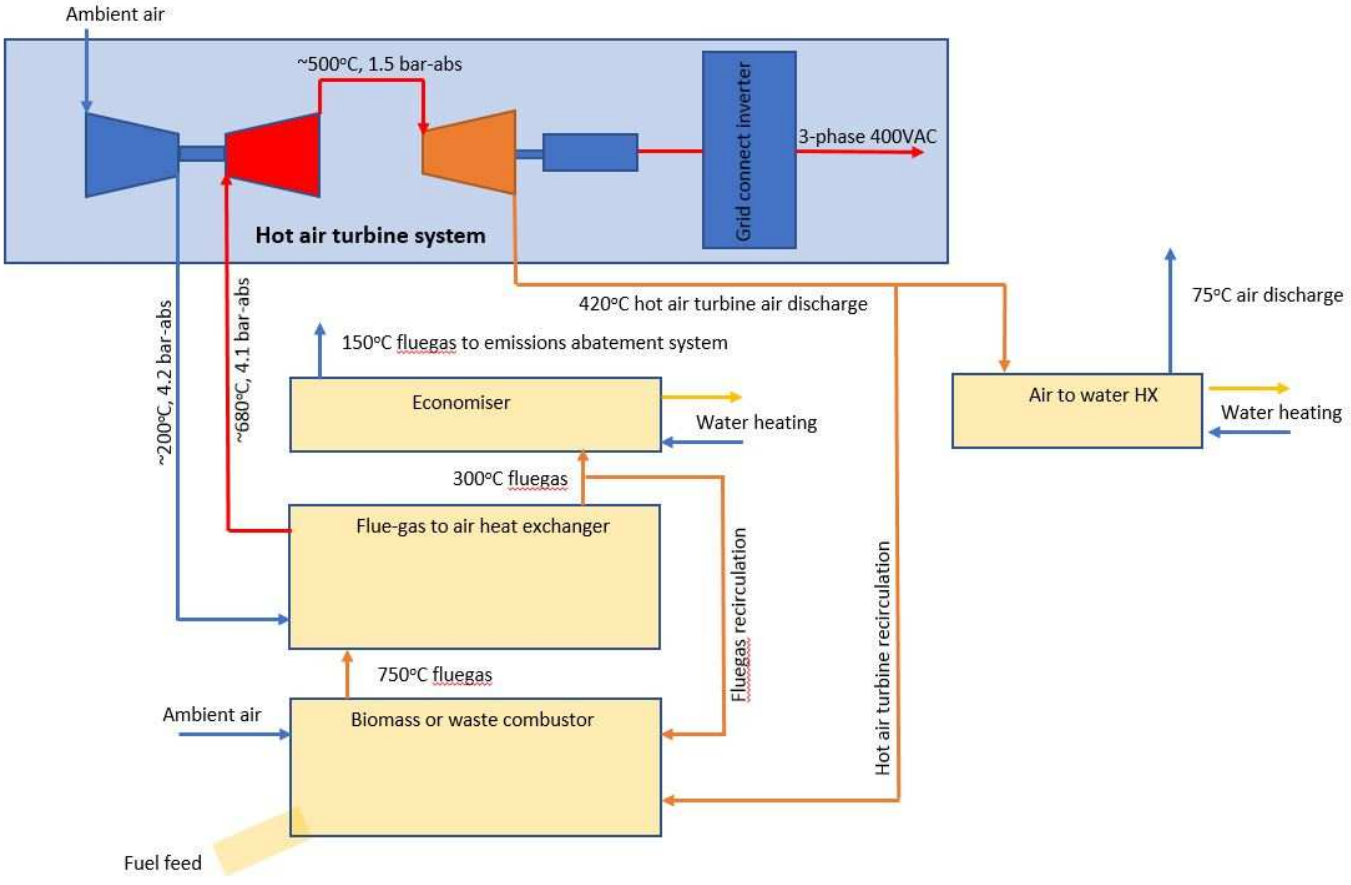
Key advantages

- Cost competitive power generation solution
- Efficiency upto 18.9%
- Very low parasitic losses (3%)
- Made of proven turbo machinery components
- Low maintenance
- Compact design
- Designed to work in all ambients up to 40°C
- High temperature output
- Designed for unmanned , 24/7 operation

Applications

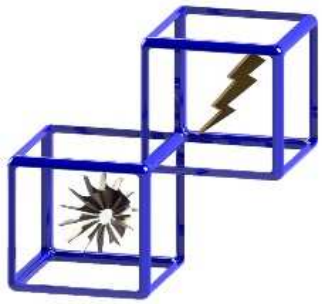
- Biomass (CHP generation)
- Waste to Energy
- Hot Air drying
- Heat Energy Recovery (from industrial processes)

Typical GoGen (CHP) Layout

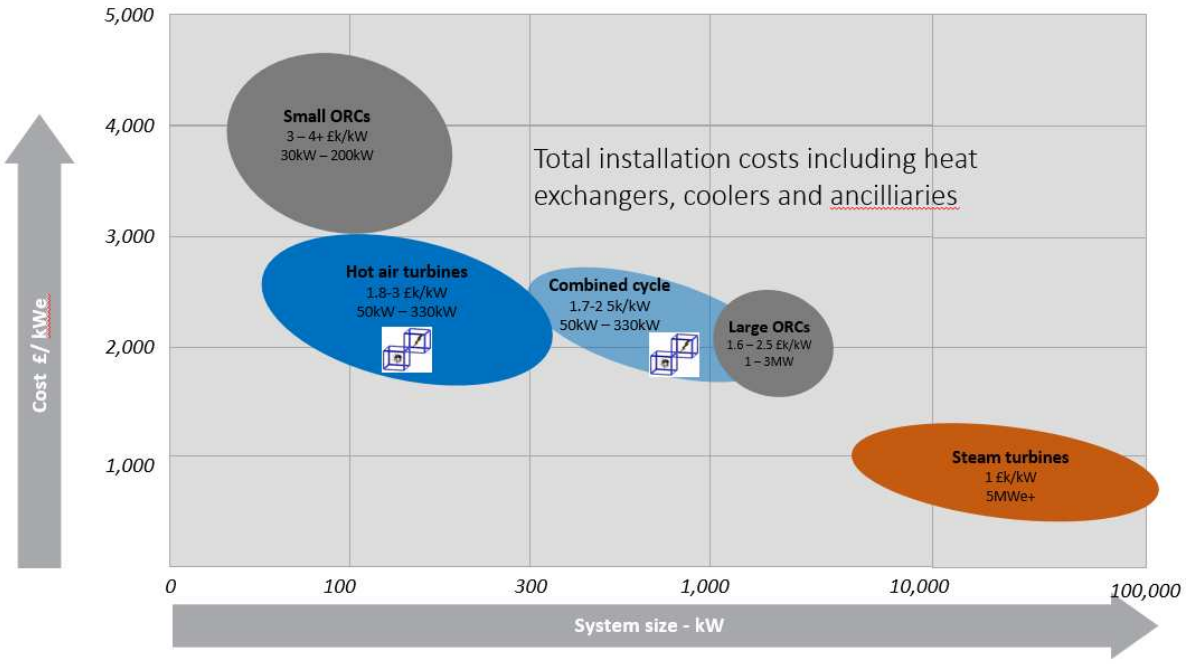


Bluebox-50	Bluebox-80	Bluebox-110	Bluebox-220	Bluebox-330

Hot Air Turbine systems by Bluebox Energy Ltd

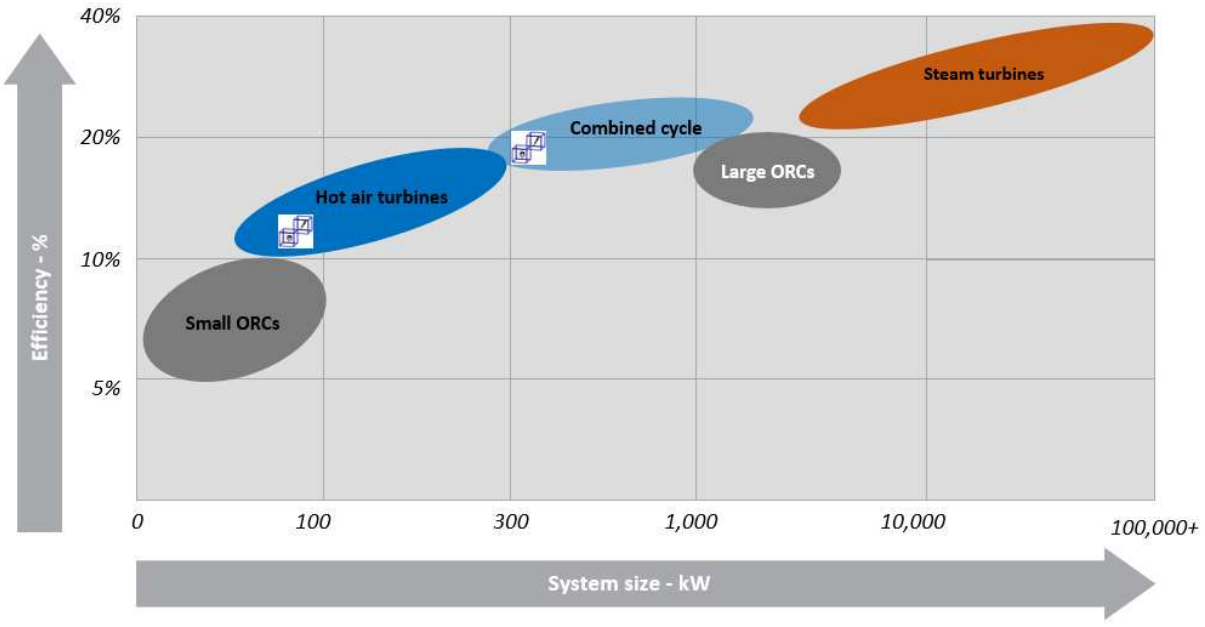


How it compares



Hot air turbines provide a cost effective solution in the range 50—1000kW. For some applications, they can also be supplemented by an organic rankine cycle to give efficiencies approaching steam turbine solutions at much lower power ratings.

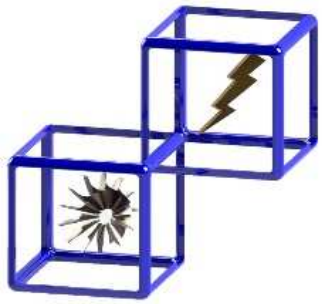
Bluebox Energy hot air turbines are also available in High Ambient (-HA) versions that can develop **full power at 40 DegC ambient temperature without any need for air cooling modules.**



"From a technical point of view, we have reached market readiness"

- Philip Luscher – CEO Schmid energy systems

Hot Air Turbine systems by **Bluebox Energy Ltd**



Bluebox-50

50 kWe Electric power generation
Upto 285 kWth Heat output
63—67 kg/h biomass or 123—131 kg/h RDF fuel burn[1]

Up to 520 Tonne CO_2 / annum saving[2]

Parameter description	Biomass		RDF	
Main heat exchanger type	STD	High perf.	STD	High perf.
Thermal input to combustor—kW [3]	317	296	501	471
Combustion air temp—DegC[4]	523.0	523.0	15.0	15.0
Flue gas temperature—°C	900.0	900.0	900.0	900.0
Flue gas mass flow—kg/hr	2376	2128	2344	2106
Hot air turbine air mass flow – kg/hr	2602	2602	2602	2106
Heat exchanger pressure –kPa-abs	268.3	268.3	268.3	268.3
Hot air turbine turbine intake temp – °C	702.1	702.1	702.1	702.1
Hot air turbine discharge temp – °C	523.0	523.0	523.0	334.8
Electrical output power – kWe	50	50	50	50
Auxilliary load—kWe	2.5	2.5	2.5	2.5
Net electrical power output—kWe	47.5	47.5	47.5	47.5
Net electrical efficiency—%	15.8%	16.9%	10.0%	10.6%
Thermal output—kWth[5]	217	205	285	274

[1] - Biomass LHV 17.0 MJ/kg, HHV 21.2 MJ/kg, RDF fuel LHV 13.8 MJ/kg, HHV 15.3 MJ/kg, 100% efficient combustion.Actual fuel burn will be higher due to less than 100% combustion and heat losses within the system. Fuel burn can be reduced by ~10% if a recuperator is added.

[2] 7000 operating hours /annum, 0.28 kg CO_2 / kWhe, 0.215 kg/kWhth and utilising a net-zero carbon fuel

[3] - Based on 15°C , 100kPa-abs ambient, 8kPa main heat exchanger pressure drop, backpressure on hot air turbine 102.1 kPa-abs with 30% fluegas recirculation

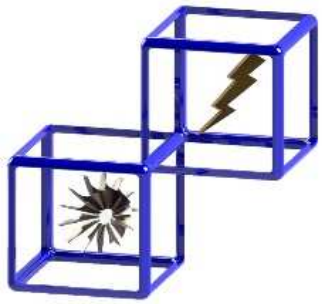
[4] - Combustion air temp for biomass combustion raised by using part of hot air turbine exhaust. Efficiency of RDF systems can be increased if combustion air can be increased

[5] - Based on 100°C output and 40°C return temp from heating network & 150°C fluegas temp to stack. Data does not include heat losses from the heat exchanger which should be deducted from this value.

Hot Air Turbine systems

by

Bluebox Energy Ltd



Bluebox-80

80 kWe Electric power generation

Upto 467 kWth Heat output

100—110 kg/h biomass or 188—207 kg/h RDF fuel burn[1]

Up to 854 Tonne CO_2 / annum saving[2]

Parameter description	Biomass		RDF	
Main heat exchanger type	STD	High perf.	STD	High perf.
Thermal input to combustor—kW [3]	515	479	791	720
Combustion air temp—DegC[4]	429.2	429.2	15.0	15.0
Flue gas temperature—°C	900.0	900.0	900.0	900.0
Flue gas mass flow—kg/hr	3600	3125	3517	3157
Hot air turbine air mass flow – kg/hr	4285	4285	4285	4285
Heat exchanger pressure –kPa-abs	412.2	412.2	412.2	412.2
Hot air turbine turbine intake temp – °C	673.3	673.3	673.3	673.3
Hot air turbine discharge temp – °C	429.2	429.2	317.8	317.8
Electrical output power – kWe	80	80	80	80
Auxilliary load—kWe	2.5	2.5	2.5	2.5
Net electrical power output—kWe	77.5	77.5	77.5	77.5
Net electrical efficiency—%	15.5%	16.7%	10.1%	11.1%
Thermal output—kWth[5]	376	331	467	422

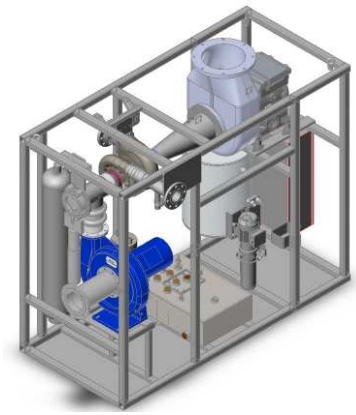
[1] - Biomass LHV 17.0 MJ/kg, HHV 21.2 MJ/kg, RDF fuel LHV 13.8 MJ/kg, HHV 15.3 MJ/kg, 100% efficient combustion. Actual fuel burn will be higher due to less than 100% combustion and heat losses within the system. Fuel burn can be reduced by ~10% if a recuperator is added.

[2] 7000 operating hours /annum, 0.28 kg CO_2 / kWhe, 0.215 kg/kWhth and utilising a net-zero carbon fuel

[3] - Based on 15°C , 100kPa-abs ambient, 8kPa main heat exchanger pressure drop, backpressure on hot air turbine 102.1 kPa-abs with 30% fluegas recirculation

[4] - Combustion air temp for biomass combustion raised by using part of hot air turbine exhaust. Efficiency of RDF systems can be increased if combustion air can be increased

[5] - Based on 100°C output and 40°C return temp from heating network & 150°C fluegas temp to stack. Data does not include heat losses from the heat exchanger which should be deducted from this value.

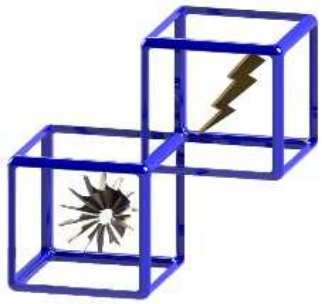


Bluebox-50 | Bluebox-80 | **Bluebox-110** | Bluebox-220 | Bluebox-330

Hot Air Turbine systems

by

Bluebox Energy Ltd



Bluebox-110

110 kWe Electric power generation

Upto 570 kWth Heat output

123—133 kg/h biomass or 237—260 kg/h RDF fuel burn[1]

Up to 1,068 Tonne CO_2 / annum saving[2]

Parameter description	Biomass		RDF	
Main heat exchanger type	STD	High perf.	STD	High perf.
Thermal input to combustor—kW [3]	630	583	995	906
Combustion air temp—DegC [4]	448.7	448.7	15.0	15.0
Flue gas temperature—°C	900.0	900.0	900.0	900.0
Flue gas mass flow—kg/hr	4464	3924	4338	3848
Hot air turbine air mass flow – kg/hr	5040	5040	5040	5040
Heat exchanger pressure –kPa-abs	421.7	421.7	421.7	421.7
Hot air turbine turbine intake temp – °C	697.5	697.5	697.5	697.5
Hot air turbine discharge temp – °C	448.7	448.7	325.9	325.9
Electrical output power – kWe	110	110	110	110
Auxilliary load—kWe	2.5	2.5	2.5	2.5
Net electrical power output—kWe	107.5	107.5	107.5	107.5
Net electrical efficiency—%	17.5%	18.9%	11.1%	12.1%
Thermal output—kWth[5]	445	388	570	513

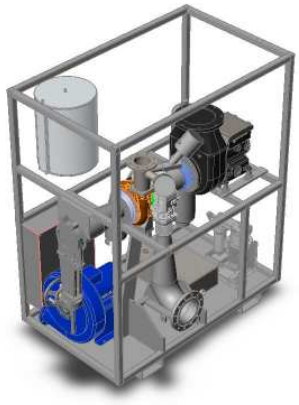
[1] - Biomass LHV 17.0 MJ/kg, HHV 21.2 MJ/kg, RDF fuel LHV 13.8 MJ/kg, HHV 15.3 MJ/kg, 100% efficient combustion. Actual fuel burn will be higher due to less than 100% combustion and heat losses within the system. Fuel burn can be reduced by ~10% if a recuperator is added.

[2] 7000 operating hours /annum, 0.28 kg CO_2 / kWhe, 0.215 kg/kWhth and utilising a net-zero carbon fuel

[3] - Based on 15°C , 100kPa-abs ambient, 8kPa main heat exchanger pressure drop, backpressure on hot air turbine 102.1 kPa-abs with 30% fluegas recirculation

[4] - Combustion air temp for biomass combustion raised by using part of hot air turbine exhaust. Efficiency of RDF systems can be increased if combustion air can be increased

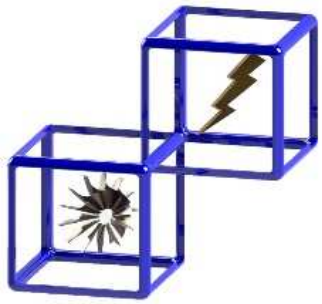
[5] - Based on 100°C output and 40°C return temp from heating network & 150°C fluegas temp to stack. Data does not include heat losses from the heat exchanger which should be deducted from this value.



Hot Air Turbine systems

by

Bluebox Energy Ltd



Bluebox-220

220 kWe Electric power generation

Upto 1550 kWth Heat output

334—364 kg/h biomass or 640—700 kg/h RDF fuel burn[1]

Up to 2,750 Tonne CO_2 / annum saving[2]

Parameter description	Biomass		RDF	
Main heat exchanger type	STD	High perf.	STD	High perf.
Thermal input to combustor—kW [3]	1799	1577	2666	2448
Combustion air temp—DegC [4]	439.4	439.4	15.0	15.0
Flue gas temperature—°C	900.0	900.0	900.0	900.0
Flue gas mass flow—kg/hr	12052	10584	11628	10404
Hot air turbine air mass flow – kg/hr	14688	14688	14688	14688
Heat exchanger pressure –kPa-abs	428.9	428.9	428.9	428.9
Hot air turbine turbine intake temp – °C	661	661	661	661
Hot air turbine discharge temp – °C	439.4	439.4	319.6	319.6
Electrical output power – kWe	220	220	220	220
Auxilliary load—kWe	7.5	7.5	7.5	7.5
Net electrical power output—kWe	212.5	212.5	212.5	212.5
Net electrical efficiency—%	12.8%	14.0%	8.25%	9.0%
Thermal output—kWth[5]	1277	1163	1550	1414

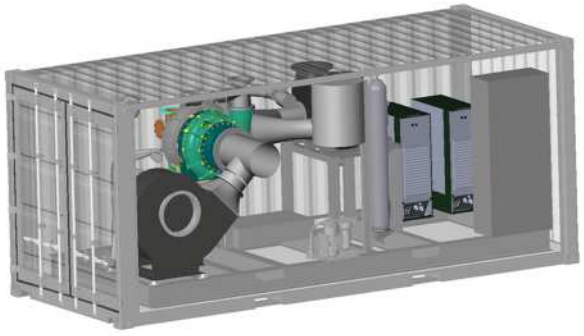
[1] - Biomass LHV 17.0 MJ/kg, HHV 21.2 MJ/kg, RDF fuel LHV 13.8 MJ/kg, HHV 15.3 MJ/kg, 100% efficient combustion. Actual fuel burn will be higher due to less than 100% combustion and heat losses within the system. Fuel burn can be reduced by ~10% if a recuperator is added.

[2] 7000 operating hours /annum, 0.28 kg CO_2 / kWhe, 0.215 kg/kWhth and utilising a net-zero carbon fuel

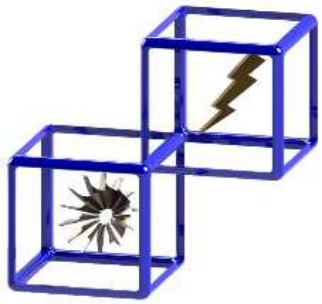
[3] - Based on 15°C , 100kPa-abs ambient, 8kPa main heat exchanger pressure drop, backpressure on hot air turbine 102.1 kPa-abs with 30% fluegas recirculation

[4] - Combustion air temp for biomass combustion raised by using part of hot air turbine exhaust. Efficiency of RDF systems can be increased if combustion air can be increased

[5] - Based on 100°C output and 40°C return temp from heating network & 150°C flue-gas temp to stack. Data does not include heat losses from the heat exchanger which should be deducted from this value.



Hot Air Turbine systems by **Bluebox Energy Ltd**



Bluebox-330

330 kWe Electric power generation
Upto 1685 kWth Heat output
390—420 kg/h biomass or 720—800 kg/h RDF fuel burn[1]

Up to 3,170 Tonne CO_2 / annum saving[2]

Parameter description	Biomass		RDF	
Main heat exchanger type	STD	High perf.	STD	High perf.
Thermal input to combustor—kW [3]	1972	1833	3059	2746
Combustion air temp—DegC [4]	443.5	443.5	15.0	15.0
Flue gas temperature—°C	900.0	900.0	900.0	900.0
Flue gas mass flow—kg/hr	13738	12168	13320	11718
Hot air turbine air mass flow – kg/hr	16344	16344	16344	16344
Heat exchanger pressure –kPa-abs	401.1	401.1	401.1	401.1
Hot air turbine turbine intake temp – °C	671	671	671	671
Hot air turbine discharge temp – °C	443.5	443.5	315.3	315.3
Electrical output power – kWe	330	330	330	330
Auxilliary load—kWe	7.5	7.5	7.5	7.5
Net electrical power output—kWe	322.5	322.5	322.5	322.5
Net electrical efficiency—%	16.7%	18.0%	10.8%	12.0%
Thermal output—kWth[5]	1414	1277	1687	1596

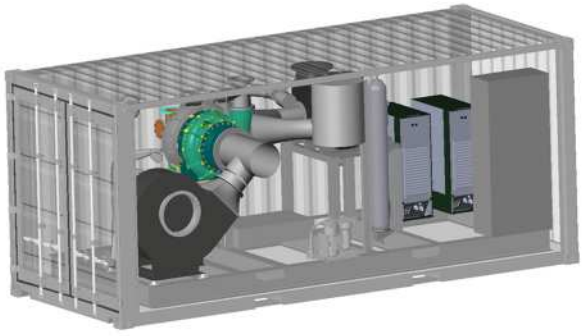
[1] - Biomass LHV 17.0 MJ/kg, HHV 21.2 MJ/kg, RDF fuel LHV 13.8 MJ/kg, HHV 15.3 MJ/kg, 100% efficient combustion. Actual fuel burn will be higher due to less than 100% combustion and heat losses within the system. Fuel burn can be reduced by ~10% if a recuperator is added.

[2] 7000 operating hours /annum, 0.28 kg CO_2 / kWhe, 0.215 kg/kWhth and utilising a net-zero carbon fuel

[3] - Based on 15°C , 100kPa-abs ambient, 8kPa main heat exchanger pressure drop, backpressure on hot air turbine 102.1 kPa-abs with 30% fluegas recirculation

[4] - Combustion air temp for biomass combustion raised by using part of hot air turbine exhaust. Efficiency of RDF systems can be increased if combustion air can be increased

[5] - Based on 100°C output and 40°C return temp from heating network & 150°C flue-gas temp to stack. Data does not include heat losses from the heat exchanger which should be deducted from this value.

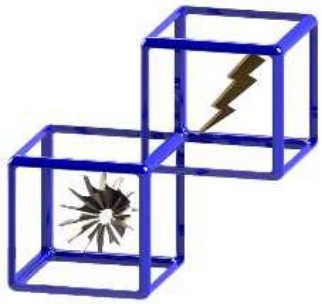


Bluebox-50 | Bluebox-80 | Bluebox-110 | Bluebox-220 | Bluebox-330

Hot Air Turbine systems

by

Bluebox Energy Ltd



Bluebox-330-HA

High Ambient

330 kWe Electric power generation

Upto 1788 kWth Heat output

420—485 kg/h biomass or 785—865 kg/h RDF fuel burn[1]

Up to 3,300 Tonne CO_2 / annum saving[2]

Parameter description	Biomass		RDF	
Main heat exchanger type	STD	High perf.	STD	High perf.
Thermal input to combustor—kW [2]	2300	1977	3305	2991
Combustion air temp—DegC	386.9	386.9	40.0	40.0
Flue gas temperature—°C	900.0	900.0	900.0	900.0
Flue gas mass flow—kg/hr	15253	13518	14796	13032
Hot air turbine air mass flow – kg/hr	18886	18886	18886	18886
Heat exchanger pressure –kPa-abs	452.0	452.0	452.0	452.0
Hot air turbine turbine intake temp – °C	623.9	623.9	623.9	623.9
Hot air turbine discharge temp – °C	386.5	386.5	386.5	386.5
Electrical output power – kWe	330	330	330	330
Auxilliary load—kWe	7.5	7.5	7.5	7.5
Net electrical power output—kWe	322.5	322.5	322.5	322.5
Net electrical efficiency—%	14.3%	16.7%	10.0%	11.0%
Thermal output—kWth[3]	1619	1345	1778	1641

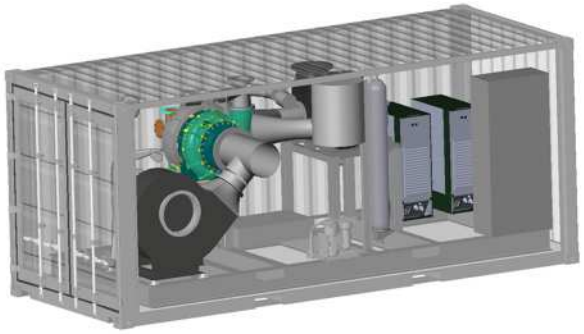
[1] - Biomass LHV 17.0 MJ/kg, HHV 21.2 MJ/kg, RDF fuel LHV 13.8 MJ/kg, HHV 15.3 MJ/kg, 100% efficient combustion. Actual fuel burn will be higher due to less than 100% combustion and heat losses within the system. Fuel burn can be reduced by ~10% if a recuperator is added.

[2] 7000 operating hours /annum, 0.28 kg CO_2 / kWhe, 0.215 kg/kWhth and utilising a net-zero carbon fuel

[3] - Based on 40°C , 100kPa-abs ambient, 8kPa main heat exchanger pressure drop, back-pressure on hot air turbine 102.1 kPa-abs with 30% fluegas recirculation

[4] - Combustion air temp for biomass combustion raised by using part of hot air turbine exhaust. Efficiency of RDF systems can be increased if combustion air can be increased

[5] - Based on 100°C output and 40°C return temp from heating network & 150°C fluegas temp to stack. Data does not include heat losses from the heat exchanger which should be deducted from this value.



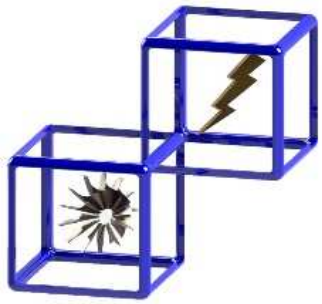
www.bluebox.energy

Bluebox-50	Bluebox-80	Bluebox-110	Bluebox-220	Bluebox-330

Hot Air Turbine systems

by

Bluebox Energy Ltd



Bluebox Energy heat recovery modules

Standard fit and available options

Scope of supply	BB-50	BB-80	BB-110	BB-220	BB-330
Bluebox Energy recovery module	●	●	●	●	●
Grid connect power electronics	●	●	●	●	●
Ancillaries (lubrication and PE cooling	●	●	●	●	●
Condition monitoring	●	●	●	●	●
Local display showing key parameters	●	●	●	●	●
CAN-based remote access	●	●	●	●	●
Modbus-based remote access	●	●	●	●	●
Software tool for remote access	○	○	○	●	●
Datalogging	○	○	○	●	●
Air inlet filtration	○	○	○	○	○
Grid connect hardware	○	○	○	○	○
Autonomous control system	○	○	○	●	●
Uninterruptible power supply	○	○	○	○	○
System encapsulation	○	○	○		
ISO 20’ Containerisation				○	○
Fire suppression system	○	○	○	○	○
Compressed air for actuators	○	○	○	○	○
Fluegas to air heat exchanger	○	○	○	○	○
Gas dilution and air turbine recirculation	○	○	○	○	○
Factory testing report & reference guide	●	●	●	●	●
One-off application engineering	○	○	○	○	○
On-site commissioning	○	○	○	○	○
12 months warranty from sign-off	●	●	●	●	●
12 months warranty extension	○	○	○	○	○
Remote support and data analysis	○	○	○	○	○

● Included ○ Optional

For further information please contact:

Bluebox Energy

Unit B1 Daedalus Business Park

Daedalus drive

Lee on Solent

Hants

PO13 9FX

Tel: +44 2392 504690

E-mail: Projects@bluebox.energy

Web: www.bluebox.energy

Customer references:

SCHMID energy solutions

Australian Government
Department of Defence
Science and Technology

Bluebox Energy
CENER
ADItech
cea
capture
COMPETITIVE SOLAR POWER TOWERS
TSK FLAGSOL
EDF

COMPAG

THM
TECHNISCHE HOCHSCHULE MITTELHESSEN

BOWMAN

ökozentrum
forschen | entwickeln | bilden

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 640905