CARBON FOOTPRINT OF A SMART HEAT TRANSFER SYSTEM

Heat exchangers represent* one of the low-carbon energy technologies that can double global energy efficiency by 2040**

*https://www.hrs-heatexchangers.com/anz/news/reducing-your-carbon-footprint-with-heat-exchangers/

**https://www.iea.org/commentaries/how-energy-efficiency-will-power-net-zero-climate-goals

HEAT TRANSFER SYSTEM OPERATIONAL CARBON EMISSIONS

Design and control of pumps affect power absorption in heat transfer systems

Power absorption of a pump in a Heat Transfer System at varying flow rates

Head in feet	% Flow	Flow (gpm)	bhp (hp)	bhp (kW)	% of time	Motor power absorbed kW in one head @ 90% efficiency	Time (hours) total: 4000 hours	Pump power absorbtion kW/h in one head	Pump power absorbtion kW-h: Tango
60.00	100	700	14.43	10.76	2	11.96	80	956.92	1913.00
57.02	95	665	12.94	9.65	2	10.72	80	857.73	1715.47
53.14	90	630	11.39	8.49	2.5	9.44	100	943.74	1887.48
49.70	85	595	10.05	7.49	3.5	8.33	140	1165.80	2331.59
46.26	80	560	8.87	6.61	4	7.35	160	1175.91	2351.81
44.53	75	525	7.69	5.73	4.5	6.37	180	1146.91	2293.81
41.52	70	490	6.77	5.05	5.5	5.61	220	1234.07	2468.14
38.94	65	455	5.91	4.41	7	4.90	280	1371.12	2742.23
36.79	60	420	5.04	3.76	6.5	4.18	260	1086.19	2172.38
34.63	55	385	4.41	3.29	7.5	3.65	300	1096.20	2192.39
33.30	50	350	3.84	2.87	8	3.19	320	1019.47	2038.94
30.76	45	315	3.28	2.45	7.5	2.72	300	815.31	1630.62
29.04	40	280	2.70	2.02	8	2.24	320	717.47	1434.95
27.75	35	245	2.13	1.59	8	1.76	320	564.75	1129.51
26.89	30	210	1.97	1.47	23.5	1.63	940	1534.34	3068.69
								Total	31371.02

The numeric values * of the energy consumptions are estimates only, provided for comparison of the two scenarios

The accuracy of the ** sensorless flow measurement falls below 95% if the flow rate is less than 455 gpm at 100 feet of head

Delta T across the load side and source side is the same and the same fluid is passing through both sides so, M source × Cp source × Delta T source = M load × Cp load × Delta T load. By making this assumption, we consider that the source pump will follow the same flow profile as the load pump but the head is not constant (Quadratic control).
The control point is not the pump head itself, it is from a pressure sensor on the heat exchanger which monitors the pressure of the fluid entering the building.

The opening of the valves on the load side will decrease the suction head available and therefore decreases the pressure on the outlet of the heat exchanger. This is picked up by the controller and it speeds up the load pump to increase the flow and make sure the pressure at the heat exchanger outlet is high enough for the building.

The closing of the valves will have the opposite effect. It will increase the head available at the suction, thereby increasing the outlet pressure at heat exchanger. The controller will reduce the pump speed to bring the pressure down to control point. This was chosen as the control strategy to make sure that constant pressure is supplied to the building at all times.

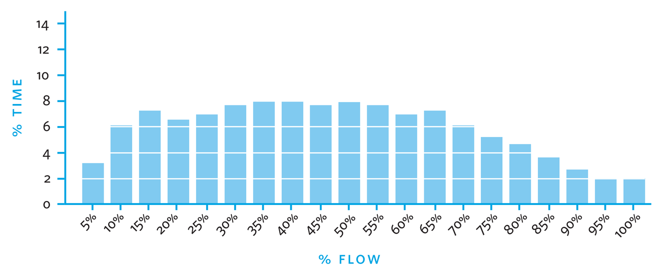
Total power absorbed by two Tangos with DE-HTS control	129,249.22 kWh
Total power absorbed by two Tangos running at constant speed at highest flow to match peak design requirement	249,763.86 kWh
Total difference	120,514.64 kWh

Assumptions

1 It is not possible to provide a realstic data for the source side pump without building temperature data. This predection is based on the follwing major assumption.

2 Delta T across the load side and source side is the same and the same fluid is passing throught both sides so, M source × Cp source × Delta T source = M load × Cp load × Delta T load. By making this assumption, we concider that the source pump will follow the same flow profile as the load pump.

Apartment/Condo High Rise Load Profile



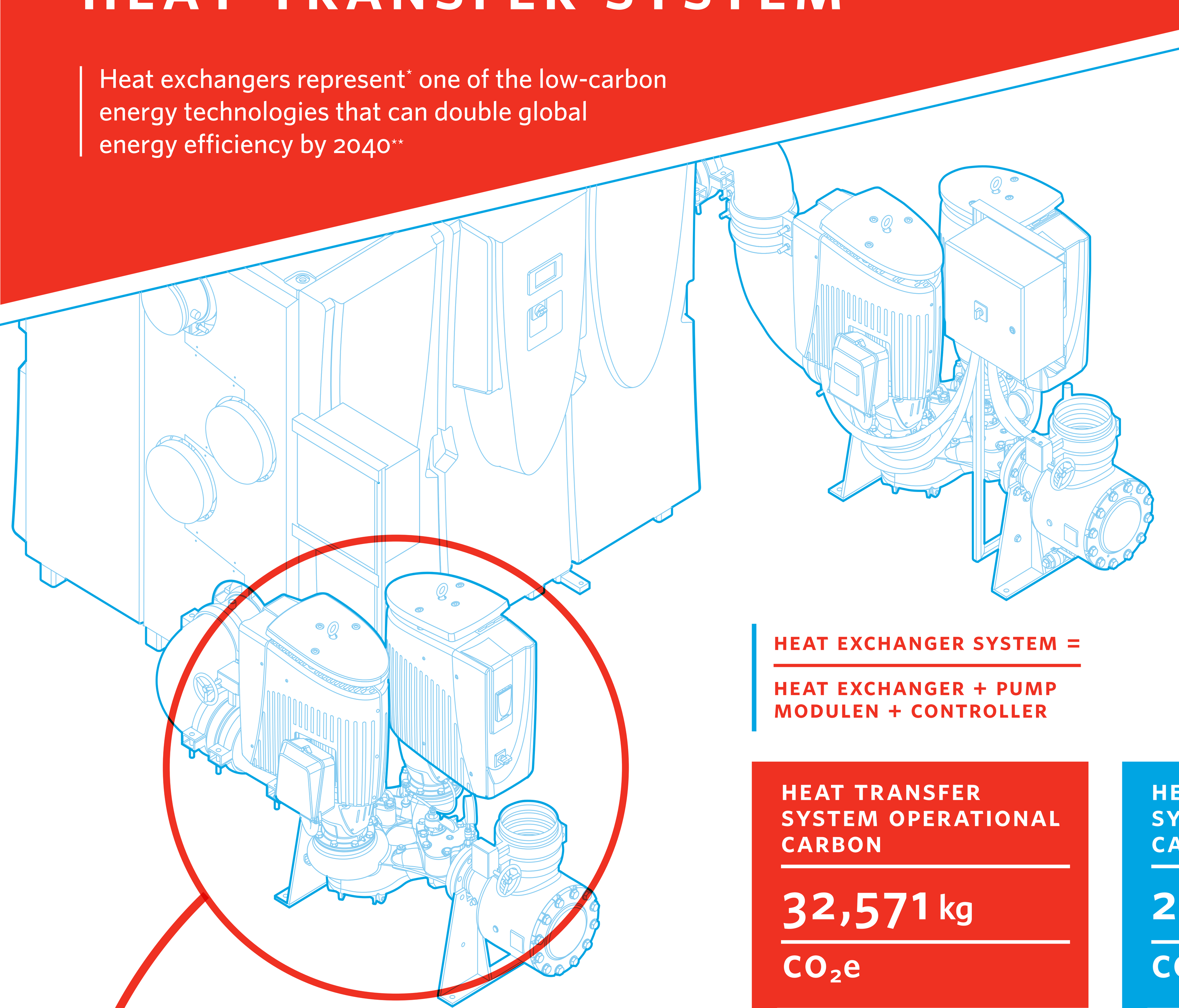
*ASHRAE Zone 5 (Illinois) Generation Factor (kg CO_2e per kWh) sourced from EPA eGrid database (2022)

An energy efficient Heat Transfer System requires:

- Designing for part loads
- Controlling for part loads
- Maintenance for optimal performance

129,249 kWh × .252 kg CO_2e PER kWh*

32,571 kg CO_2e



HEAT EXCHANGER SYSTEM =

HEAT EXCHANGER + PUMP MODULEN + CONTROLLER

HEAT TRANSFER SYSTEM OPERATIONAL CARBON

32,571 kg CO_2e

HEAT TRANSFER SYSTEM EMBODIED CARBON

28,756 kg CO_2e

Integrated design is critical to decarbonization

The keys to designing a low carbon Heat Transfer System are: 1 **integration**, 2 **using the latest technologies**, and 3 **control strategies**. Combining new technologies with old technologies and not integrating them is a common mistake. When an entire system is designed together, fully integrated, and sized correctly for the application, the motor can be smaller, the pump can be smaller (achieving lower embodied carbon) and the system can run at higher efficiency (achieving the lowest operational carbon).

A systems approach will move heat exchangers from a passive mechanical component to an active component of a Heat Transfer System that operates on intelligence and delivers optimized performance.

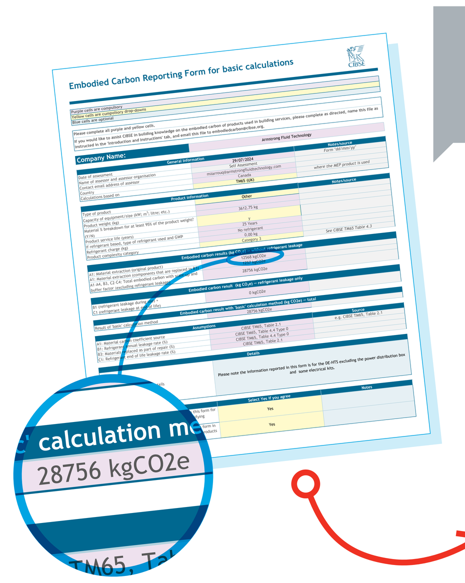
1 **Integration:** full integration leverages the full potential of individual components

2 **Latest technologies:** modern components and solution designs can save up to 75% in carbon over traditional solutions

3 **Control strategies:** optimized modulation and staging of components boosts efficiency

HEAT TRANSFER SYSTEM EMBODIED CARBON CALCULATION

TM65 methodology using global GWP values



Advanced technology in Heat Transfer Systems supports the use of smaller, more efficient components that minimize energy consumption and embodied carbon.

TM65 forms of major Heat Transfer System component data provided by suppliers

Triplex Heat Transfer System	Weight (kg)	Quantity	Embodied carbon (kg CO_2e)	Weight (kg) of components	Total embodied carbon (kg CO_2e) by component
Pump module	379.2	2	3017	758.4	6034
Heat exchanger(s)	306.5	3	3008	919.5	9024
Heat exchanger frame (carbon steel)	498.9	1	2754	498.9	2754
Control panel	32.4	1	709	32.4	709
Coupling	1	36	5	36	180
Check valve	1	6	4	4	24
Fittings					
Butterfly valve	1	6	4	6	24
(RTD) Resistance Temperature Detector	.255 kg	2	4	.5 kg	8
Suction guide	71.1	2	237	142.2	474
Subtotal (supplier TM65)				2,397.80	19,231
System balance				1,183.51	9,525

Supply chain data:

- HX
- Pipe fittings and valves
- Resistance temperature detector
- Pressure sensor
- Drive
- Control panel
- Shroud

Note: Values presented are representative of the major components, excluding power distribution box and some electrical kits.

* Embodied carbon can be substantially lowered (more than 50% of a traditional solution) if the best solutions available in market are used

* Embodied carbon is measurable today through LCA/TM65 to facilitate the best sourcing decisions

PUMP OPERATIONAL CARBON EMISSIONS

Systems approach to sizing a pump for optimized heat transfer performance
The pump is the driving force for heat transfer across the heat exchanger

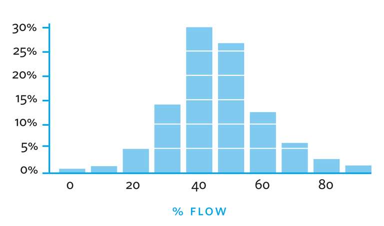
Pump energy report

Project name	HTS operational energy		
Date submitted	2024-07-31	Pump ref/tag	Tango 4332 0406C-25
Browser app version	2.5		
Building type	Apartment-condo, high rise	Region	US
Base case data			
Manufacturer	Armstrong	Age of pump	1
Pump station configuration	Var.spd_var.flw (H)	Feedback method	DP setpoint control curve
Duty pumps	2	Staging method	Capacity based
Design flow per pump (gpm)	700	Design head (ft)	100
Motor efficiency	91%	Duty pt. efficiency (hydraulic)	70%
Design motor (Hz)	60	Annual operating hours	4,000
Power (hp)	25.0	Electricity cost	0.13
Energy consumption (kWh)	57,456	Annual operating cost	27,469
Replacement case data			
Pump station configuration	DE_var.spd_var.flw (H)	Feedback method	Quadratic control curve
Duty pumps	2	Staging method	Efficiency based
Design flow per pump (gpm)	700	Head capability over design (min to max)	1% to 1%
Design head (ft) (min)	93	Design head (ft) (max)	99
Motor efficiency	93%	Duty point efficiency (hydraulic)	72%
Design motor speed (Hz)	60	Annual operating hours	4,000
% motor efficiency improvement	+2%	% hydraulic efficiency improvement	0%
Power (hp)	25.0	Electricity cost	0.13
Energy consumption min. (kWh)	45,536	Energy consumption max. (kWh)	64,729
Minimum annual operating cost	15,920	Maximum annual operating cost	15,920
Energy saving			
Annual saving (min. to max.)	11,550 to 11,550	CO_2 emission reduction	8 to 8 tons/annum
Percent Saving	21% to 21%		

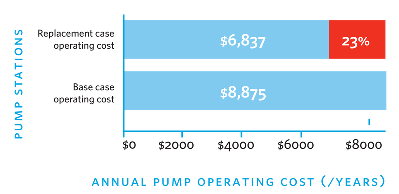
Assumptions

1 Age of base case pumps as one years
2 Head Overspec. range: 1% to 1%

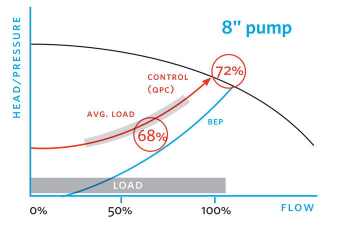
Load profile



Pump station operating cost



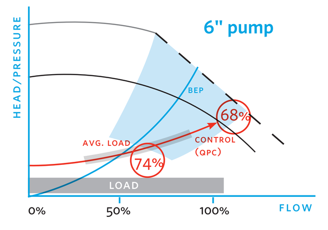
Traditional wall-mount VFD



Traditional pump with design point to the left of BEP

Design point	72%
Average load	68%

Design Envelope pump



Design Envelope pump with design point to the right of BEP

Design point	68%
Average load	74%

45,536 kWh × .252 kg CO_2e PER kWh

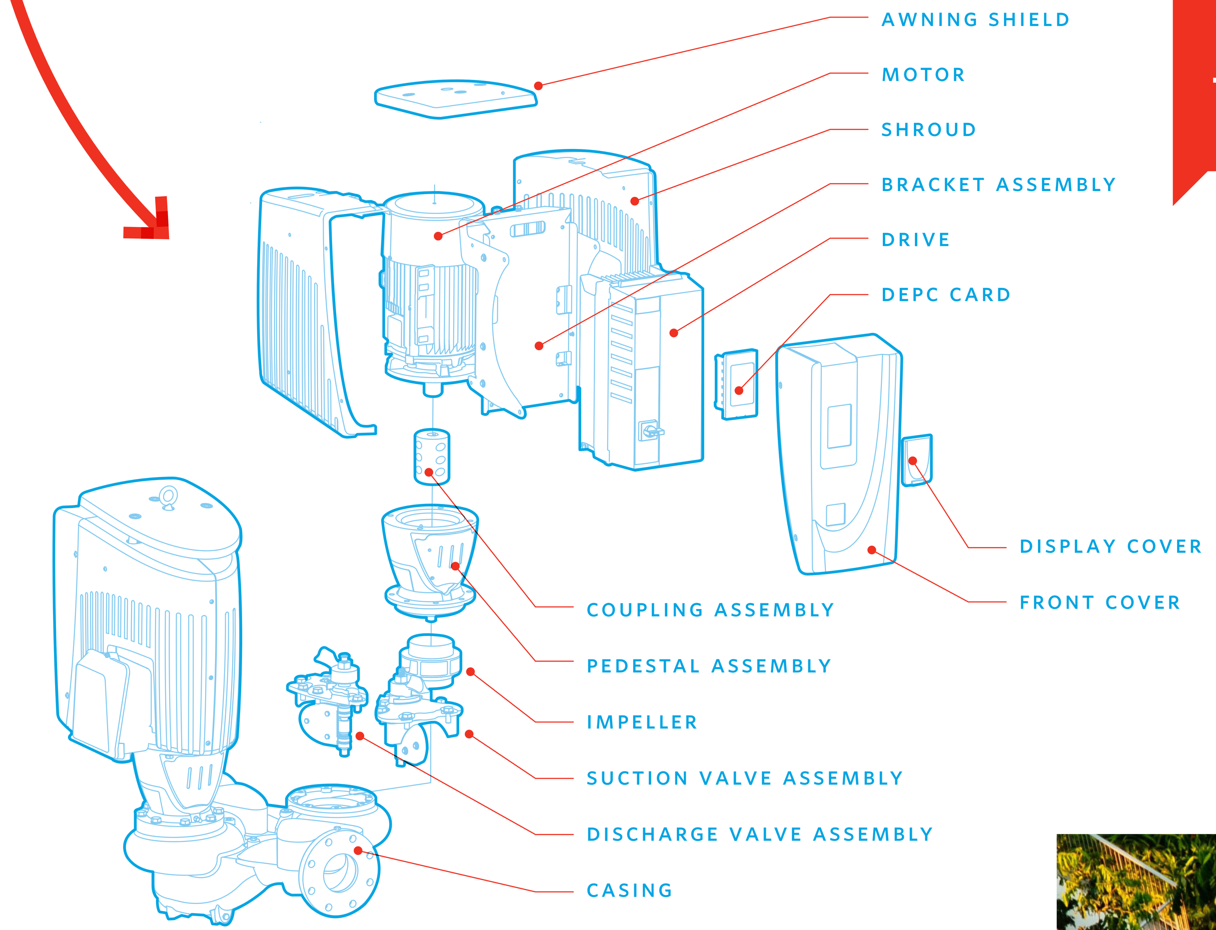
11,475 kg CO_2e

Selecting the right pump technology supports the use of smaller, more efficient pumps that minimize energy consumption and embodied carbon.

* The data presented covers one year (4000 operational hours at part load)

CARBON FOOTPRINT OF A PUMP

The pump is the driving force for heat transfer across the heat exchanger because it creates the pressure drop



PUMP OPERATIONAL CARBON

11,475 kg CO_2e

PUMP EMBODIED CARBON

2793 kg CO_2e

PUMP EMBODIED CARBON

openLCA methodology

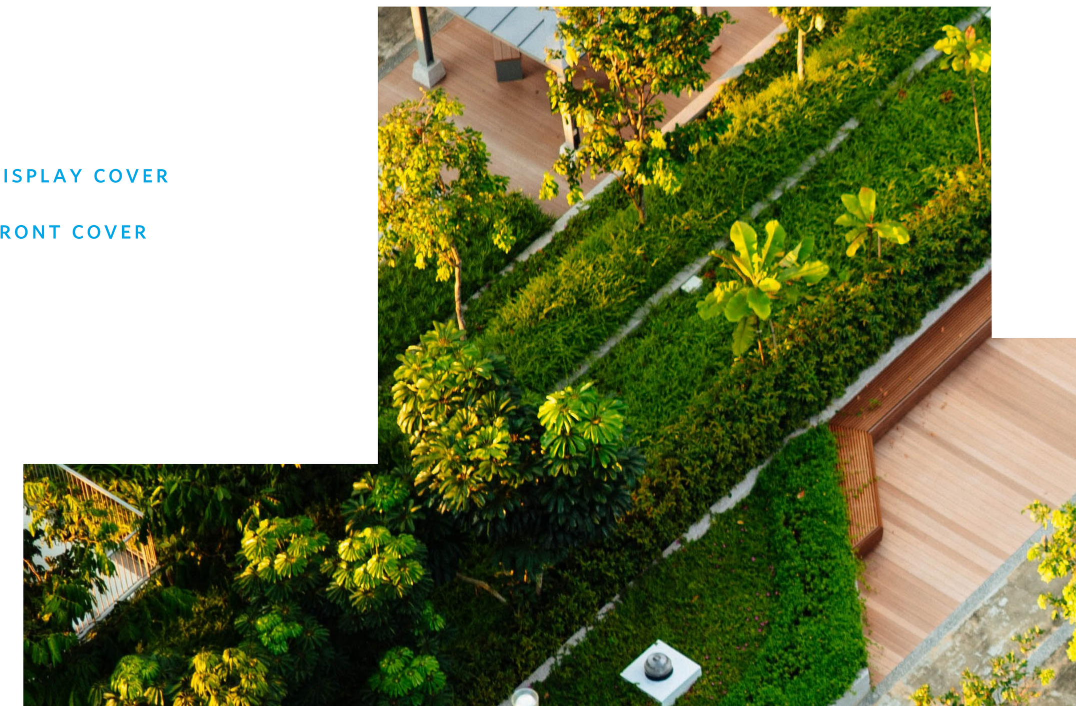
Design Envelope 4332 0406C-25.0

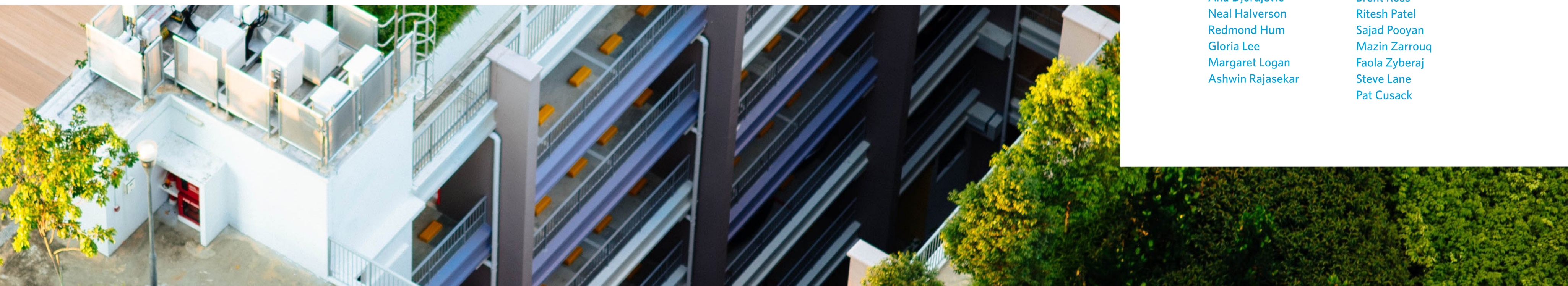
Quantity	Part/assembly	Weight (kg)	Weight percentage	Carbon kg CO_2e
2	Motor	136.8	36.08%	36.08%
1	Casing	96.15	25.37%	25.37%
2	Drive	42.4	11.18%	11.18%
2	Pedestal assembly	36.62	9.66%	9.66%
1	Impeller (left + right)	6.80	1.79%	1.79%
2	Bracket assembly	26.74	7.05%	7.05%
2	Shrouds (enclosure)	10.44	2.75%	2.75%
1	Suction valve assembly	10.1	2.66%	2.66%
1	Discharge valve assembly	7.79	2.05%	2.05%
2	Coupling assembly	3.28	0.86%	0.86%
2	Display cover + DEPC card	0.67	0.18%	0.18%
2	Other	1.42	0.37%	0.37%
	Other	379.21	100.00%	2792.92
Total		**379.21**	**100.00%**	**1.00**

BOM WITH DATA SOURCES CONSIDERED

Design Envelope 4332 0406C-25.0

Part description	Part number	Material	Weight (Kg)	Manufacturing process	Manufacturing location	Quantity	Total weight (kg)	Data source	Data collection year
Motor	72538613-069		68.4		France	2	136.8	Supplier	2024
Drive	N/A		21.2		France	2	42.4	Supplier	2024
Casing ASME 125# E-Coated	428876-211	E-coat CI A48-30	96.15	Sand casting	India	1	96.15		
Suction valve Tango 4"	429039-023	Steel/SST/cast iron/rubber	10.1	Casting/machining	Canada	1	10.1		
Discharge valve Tango 4"	429039-024	Steel/SST/cast iron/rubber	6.8	Casting/machining	Canada	1	6.8		
Pedestal assembly	428883-601	Cast iron/SST/carbon steel	18.31	Casting/machining	India	2	36.62	Part dwg	
Coupling assembly	428904-000	Aluminum/SST/steel	1.64	Machining	India	2	3.28		
Impeller (left + right)	428873-271 428873-271	ASTM A890/A890M Duplex CD4MCUN (1B)	3.5 3.3	lost-wax casting	India	1	6.8		
Shroud (front + left + right + awning shield)	428951-000 428952-000 428953-000 428954-000	ABS polylac PA-757 and ASA kibilac PW-978B composite	5.22	Thermo-forming	China	2	10.44	Part dwg	2024
Bracket assembly (main + left + right)	428955-001 428957-001 428958-001	Carbon steel	13.37	Forming	Canada	2	26.74	Part dwg	
Display cover assembly DEPC card	429041-006 428818-000	Plastic + SST + electronics	0.335		Canada	2	0.67	Part dwg	
Other		Steel	1.42		Canada	1	1.42		





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