

Excel VBA to Python Migration Plan

HC2 Thermal Calculator System

Generated: 2025-10-22 **Project:** sigma-thermal **Objective:** Convert Excel VBA-based thermal calculation system to standalone Python modules

Executive Summary

This plan outlines the migration of a comprehensive thermal heating system design tool from Excel VBA to Python. The system consists of:

- **Engineering-Functions.xlam:** 521 VBA functions across 11 modules (~15,824 lines)
- **HC2-Calculators.xlsm:** 27 worksheets with integrated calculations and document generation (~3,170 lines VBA)
- **293+ named ranges** used for data flow between calculations
- **Multiple P&ID diagrams** and printable outputs

The migration will preserve all calculation accuracy while modernizing the architecture for maintainability, testability, and scalability.

Phase 1: Analysis & Setup

1.1 Repository Structure

```
sigma-thermal/
├── src/
│   ├── sigma_thermal/
│   │   ├── __init__.py
│   │   ├── combustion/           # CombustionFunctions.bas
│   │   ├── fluids/              # FluidFunctions.bas
│   │   ├── heat_transfer/       # RadiantFunctions, ConvectionFunctions
│   │   ├── engineering/        # EngineeringFunctions.bas
│   │   ├── pricing/            # PricingFunctions.bas
│   │   ├── water_bath/         # WaterBathFunctions.bas
│   │   ├── wood_fuel/          # WoodFunctions.bas
│   │   ├── refprop/            # RefpropCode.bas integration
│   │   ├── calculators/        # High-level calculation workflows
│   │   ├── data/               # Lookup tables, constants
│   │   ├── io/                 # Input/output handling
│   │   └── reporting/          # Document generation
│   └── tests/
│       ├── unit/
│       ├── integration/
│       └── validation/         # Excel vs Python comparison
└── data/
    └── lookup_tables/
```

```
|   |   | equipment_specs/
|   |   | validation_cases/
|   |   |
|   |   | docs/
|   |   | examples/
|   |   | requirements.txt
|   |   | setup.py
```

1.2 Development Environment Setup

Core Dependencies:


```
numpy>=1.24.0      # Numerical computing
scipy>=1.10.0      # Scientific computing
pandas>=2.0.0      # Data manipulation
pint>=0.22         # Unit conversions
CoolProp>=6.4.3    # Thermodynamic properties (replaces Refprop)
openpyxl>=3.1.0    # Excel file handling
xlwings>=0.30.0    # Excel integration during migration
pydantic>=2.0      # Data validation
pytest>=7.4.0      # Testing framework
hypothesis>=6.82.0 # Property-based testing
black              # Code formatting
mypy              # Type checking
```

Optional Dependencies:

```
matplotlib>=3.7.0 # Plotting
reportlab>=4.0.0   # PDF generation
docxtpl>=0.16.0    # Word document generation (quotations)
streamlit>=1.25.0  # Web UI (future)
```

1.3 VBA Code Extraction

Action Items:

- 1.  Extract VBA code using **olevba** tool
- 2. Parse VBA modules into structured format
- 3. Create function inventory with signatures
- 4. Map inter-function dependencies
- 5. Identify external library calls (Refprop)
- 6. Extract lookup tables from Excel ranges
- 7. Document calculation workflows

Tools:

```
# Extract VBA code
olevba sources/Engineering-Functions.xlam > extracted/engineering-
functions.vba
olevba sources/HC2-Calculators.xlsm > extracted/hc2-calculators.vba

# Parse function signatures
python scripts/parse_vba_signatures.py

# Extract Excel data tables
python scripts/extract_lookup_tables.py
```

Phase 2: Core Module Development

2.1 Module: Combustion (**combustion/**)

Source: **CombustionFunctions.bas** (Engineering-Functions.xlam)

Key Functions:

- **FlueGasEnthalpy()** - Flue gas enthalpy calculations
- **HHVMass()** / **LHVMass()** - Heating value calculations
- **FlameTemp()** - Adiabatic flame temperature
- **RecircTemp()** - Flue gas recirculation temperature
- **Efficiency()** - Combustion efficiency
- **POC_***() family - Products of combustion (CO₂, H₂O, N₂, O₂, SO₂)
- **AirFuelRatio()** / **AirFuelRatioVol()** - Stoichiometric calculations
- **NOxConv()** / **COConv()** - Emissions unit conversions

Python Module Structure:

```
# combustion/__init__.py
# combustion/enthalpy.py - Enthalpy calculations
# combustion/heating_values.py - HHV/LHV
# combustion/flame_temp.py - Temperature calculations
# combustion/emissions.py - NOx, CO calculations
# combustion/products.py - Products of combustion
# combustion/air_fuel.py - Stoichiometry
# combustion/constants.py - Combustion constants
```

Implementation Notes:

- Use **pint** for unit handling
- Polynomial coefficients for enthalpy correlations (EnthalpyCO₂, EnthalpyH₂O, etc.)
- Support both mass and volumetric basis
- Handle multiple fuel types (gas composition arrays)
- Validate inputs (composition sums to 1.0, positive values)

Test Strategy:

- Unit tests for each function
- Validation against Excel for 50+ test cases
- Property-based tests (compositions sum to 1, energy balance)

2.2 Module: Fluids (fluids/)

Source: `FluidFunctions.bas` (Engineering-Functions.xlam)

Key Functions:

- `FluidDensity()` / `FluidSpecificHeat()` / `FluidViscosity()` / `FluidThermalConductivity()`
- Dow A/J thermal fluid property functions
- `LiquidAmineCp()` - Amine heat capacity
- Various thermal fluid correlations

Python Module Structure:

```
# fluids/__init__.py
# fluids/properties.py - Generic fluid property interface
# fluids/thermal_fluids.py - Dow A, Dow J, etc.
# fluids/amines.py - Amine solutions
# fluids/water_steam.py - Water/steam properties
# fluids/database.py - Fluid property database
```

Implementation Notes:

- Use CoolProp for standard fluids (water, air, etc.)
- Implement custom correlations for proprietary fluids (Dow A, Dow J)
- Create abstract base class for fluid property interfaces
- Cache property calculations for performance
- Handle phase changes appropriately

Integration:

- CoolProp replaces much of Refprop functionality
- Maintain backward compatibility with VBA function signatures
- Add SI/Imperial unit handling

2.3 Module: Heat Transfer (heat_transfer/)**Sources:**

- `RadiantFunctions.bas` (Engineering-Functions.xlam)
- `ConvectionFunctions.bas` (Engineering-Functions.xlam)

Key Functions:

- Radiant section calculations
- Convection correlations (Nusselt, Reynolds, Prandtl numbers)
- Tube wall temperature calculations
- Heat exchanger sizing
- W-beam specific calculations (relates to Sheet: W-Beam Data 2.0)

Python Module Structure:

```
# heat_transfer/__init__.py
# heat_transfer/radiant.py - Radiant heat transfer
# heat_transfer/convection.py - Convective heat transfer
# heat_transfer/tube_calcs.py - Tube-side calculations
# heat_transfer/dimensionless.py - Nu, Re, Pr correlations
# heat_transfer/heat_exchangers.py - HX sizing/rating
# heat_transfer/w_beam.py - W-beam specific calculations
```

Implementation Notes:

- Implement standard heat transfer correlations
- Validate against established references (Incropera, HEDH)
- Handle iterative calculations (tube wall temps)
- Support multiple tube configurations

2.4 Module: Engineering Utilities (**engineering/**)

Source: **EngineeringFunctions.bas** (Engineering-Functions.xlam)

Key Functions:

- **Interpolate()** - Linear interpolation
- **TubeWallTemp()** / **TubeWallTemperature()**
- **DINFlangeRating()**
- Duct/pipe sizing functions
- Expansion tank sizing
- Valve Cv calculations

Python Module Structure:

```
# engineering/__init__.py
# engineering/interpolation.py - Interpolation utilities
# engineering/pipe_sizing.py - Pipe/duct sizing
# engineering/tanks.py - Tank sizing
# engineering/valves.py - Valve sizing
# engineering/flanges.py - Flange ratings
```

2.5 Module: Pricing (**pricing/**)

Source: **PricingFunctions.bas** (Engineering-Functions.xlam)

Python Module Structure:

```
# pricing/__init__.py
# pricing/equipment.py - Equipment cost estimation
# pricing/materials.py - Material cost calculations
# pricing/labor.py - Labor cost estimation
# pricing/markup.py - Markup calculations
```

Note: Extract pricing data from "Item Lookup" and "Item Table" sheets

2.6 Module: Wood Fuel (wood_fuel/)

Source: WoodFunctions.bas (Engineering-Functions.xlam)

Key Functions:

- WoodLHV() / WoodHHV() - Wood fuel heating values
- WoodAirFuelRatio()
- Wood products of combustion

Python Module Structure:

```
# wood_fuel/__init__.py
# wood_fuel/heating_values.py
# wood_fuel/combustion.py
```

2.7 Module: Water Bath (water_bath/)

Source: WaterBathFunctions.bas (Engineering-Functions.xlam)

Python Module Structure:

```
# water_bath/__init__.py
# water_bath/calculations.py - Water bath specific calcs
```

Phase 3: Calculator Workflows

3.1 High-Level Calculator Classes

Purpose: Replicate the calculation flow from HC2-Calculators.xlsm worksheets

Key Calculators:

```
# calculators/__init__.py
# calculators/heater_calculator.py - Main heater sizing
```

```
# calculators/budget_calculator.py - Cost estimation
# calculators/expansion_calculator.py - Expansion tank sizing
# calculators/secondary_loop.py - Secondary loop balance
# calculators/equipment_sizing.py - Equipment area calculations
# calculators/burner_sizing.py - Burner selection
# calculators/fuel_train.py - Fuel train design
```

Implementation Approach:

1. Each calculator is a class with:
 - Input validation (Pydantic models)
 - Calculation methods
 - Output generation
 - Unit handling
2. Calculators compose core module functions
3. Support both iterative and direct calculation modes
4. Log intermediate results for debugging

Example Structure:

```
from pydantic import BaseModel, validator
from typing import Optional
import pint

ureg = pint.UnitRegistry()

class HeaterInputs(BaseModel):
    """Input parameters for heater calculator"""
    duty: float # BTU/hr or kW
    duty_units: str = "BTU/hr"
    fluid_type: str
    flow_rate: float
    temp_in: float
    temp_out: float
    # ... 50+ input parameters

    @validator('duty')
    def duty_positive(cls, v):
        if v <= 0:
            raise ValueError('Duty must be positive')
        return v

class HeaterCalculator:
    """Main heater sizing calculator"""

    def __init__(self, inputs: HeaterInputs):
        self.inputs = inputs
        self.results = {}

    def calculate(self):
        """Execute full calculation sequence"""
```

```
        self._validate_inputs()
        self._calculate_thermal_duty()
        self._size_radiant_section()
        self._size_convection_section()
        self._calculate_efficiency()
        self._select_burners()
        self._design_fuel_train()
        return self.results

def _calculate_thermal_duty(self):
    """Calculate required thermal duty"""
    from sigma_thermal.fluids import FluidProperties
    from sigma_thermal.heat_transfer import DutyCalculator
    # Implementation
```

3.2 Worksheet-to-Calculator Mapping

Excel Worksheet	Python Calculator	Priority
New Primary Inputs	inputs.InputManager	High
Heater Calcs	calculators.HeaterCalculator	High
New Budget	calculators.BudgetCalculator	High
W-Beam Data 2.0	heat_transfer.WBeamCalculator	High
Expansion Calculation	calculators.ExpansionCalculator	Medium
Secondary Loop Balance	calculators.SecondaryLoopCalculator	Medium
Heater Equip Area	calculators.EquipmentAreaCalculator	Medium
Air and Exhaust Equip Area	calculators.AirExhaustSizing	Medium
Burner and Controls Equip Area	calculators.BurnerControlsSizing	Medium
Fuel Train Equip Area	calculators.FuelTrainSizing	Medium
Lookups	data.LookupTables	High
Internal Datasheet	Integrated into calculators	Medium
Qtion	calculators.HeatDutyCalculator	High

Phase 4: Data Management

4.1 Lookup Tables & Reference Data

Source: Extract from Excel named ranges and "Lookups" sheet

Data Structure:


```
# data/__init__.py
# data/lookup_tables.py - Table access interface
# data/equipment_data.py - Equipment specifications
# data/materials.py - Material properties
# data/standards.py - Code standards (ASME, NEMA, etc.)
```

Storage Format:

- JSON for simple tables
- CSV for large datasets
- SQLite for complex relational data (future)

Example Data:

```
# data/tables/burner_models.json
{
  "manufacturers": {
    "Manufacturer_A": {
      "models": [
        {
          "model": "Model-100",
          "capacity_min": 1000000,
          "capacity_max": 5000000,
          "units": "BTU/hr",
          "turndown": 10
        }
      ]
    }
  }
}
```

4.2 Named Range Mapping

Challenge: 293+ named ranges act as global variables in Excel

Solution:

1. Create configuration management system
2. Group related parameters into data classes
3. Use dependency injection for calculator configuration

Example:

```
from dataclasses import dataclass
from typing import Optional

@dataclass
class SystemConfiguration:
```

```

    """Maps to Excel named ranges for system config"""
    heater_type: str # Heater_Type named range
    heater_model: str # Heater_Models
    configuration_style: str # Configuration_Style
    installation_environment: str # InstallationEnvironment
    area_classification: str # Area_Classification

@dataclass
class FluidParameters:
    """Fluid-related named ranges"""
    fluid_type: str # FluidType
    flow_rate_1: float # FluidFlow1
    temp_in_1: float # FluidTempIn1
    temp_out_1: float # FluidTempOut1
    # ... additional fluid loops

```

4.3 Input/Output Management

```

# io/__init__.py
# io/excel_reader.py - Read Excel files (backward compatibility)
# io/excel_writer.py - Write Excel outputs
# io/json_io.py - JSON format support
# io/yaml_io.py - YAML format support
# io/validators.py - Input validation

```

Supported Input Formats:

- Excel (.xlsx) - backward compatibility
- JSON - modern API
- YAML - human-readable config
- Python dict - programmatic use

Example:

```

from sigma_thermal.io import InputReader

# Load from Excel (migration period)
inputs = InputReader.from_excel("customer_project.xlsx")

# Load from JSON (target format)
inputs = InputReader.from_json("customer_project.json")

# Programmatic
inputs = InputReader.from_dict({
    "heater_type": "HC2-1500",
    "duty": 15000000,
    # ...
})

```

Phase 5: Testing & Validation

5.1 Test Strategy

Test Levels:

1. **Unit Tests** - Individual functions (target: >90% coverage)
2. **Integration Tests** - Module interactions
3. **Validation Tests** - Python vs Excel comparison
4. **Regression Tests** - Prevent breaking changes
5. **Property-Based Tests** - Hypothesis testing

5.2 Validation Test Suite

Approach: Create 20-50 complete validation cases

Process:

1. Run calculation in Excel workbook
2. Export all inputs and outputs
3. Run same calculation in Python
4. Compare all results within tolerance

Tolerance Levels:

- Core calculations: 0.01% difference
- Iterative solutions: 0.1% difference
- Rounded values: 1% difference

Validation Test Structure:

```
# tests/validation/test_heater_calcs.py
import pytest
import pandas as pd
from sigma_thermal.calculators import HeaterCalculator

class TestHeaterValidation:

    @pytest.fixture
    def excel_results(self):
        """Load Excel calculation results"""
        return pd.read_excel("validation_cases/case_01_excel.xlsx")

    def test_case_01_natural_gas_heater(self, excel_results):
        """Validate against Excel Case 01"""
        # Load inputs
        inputs = load_validation_inputs("case_01")

        # Run Python calculation
        calc = HeaterCalculator(inputs)
```

```

        results = calc.calculate()

        # Compare results
        assert results.duty == pytest.approx(excel_results['duty'],
rel=1e-4)
        assert results.efficiency ==
pytest.approx(excel_results['efficiency'], rel=1e-3)
        # ... compare all outputs

```

5.3 Test Data Generation

Tools:

```

# scripts/generate_validation_cases.py
# Purpose: Run Excel calculations and export results

import xlwings as xw
import json

def generate_validation_case(case_name: str):
    """Generate validation case from Excel workbook"""
    wb = xw.Book("HC2-Calculators.xlsm")

    # Read all inputs (from named ranges)
    inputs = {}
    for name in wb.names:
        inputs[name.name] = name.refers_to_range.value

    # Trigger calculation
    wb.macro("HCCalc")()

    # Read all outputs
    outputs = {
        "duty": wb.sheets["Heater Calcs"].range("DutyCell").value,
        "efficiency": wb.sheets["Heater
Calcs"].range("EfficiencyCell").value,
        # ... all outputs
    }

    # Save
    with open(f"validation_cases/{case_name}.json", "w") as f:
        json.dump({"inputs": inputs, "outputs": outputs}, f, indent=2)

```

5.4 Continuous Integration

GitHub Actions Workflow:

```

# .github/workflows/tests.yml
name: Tests

```

```

on: [push, pull_request]

jobs:
  test:
    runs-on: ubuntu-latest
    steps:
      - uses: actions/checkout@v3
      - name: Set up Python
        uses: actions/setup-python@v4
        with:
          python-version: '3.11'
      - name: Install dependencies
        run: |
          pip install -e .[dev]
      - name: Run tests
        run: |
          pytest tests/ --cov=sigma_thermal --cov-report=xml
      - name: Run validation tests
        run: |
          pytest tests/validation/ --verbose
      - name: Type checking
        run: |
          mypy src/sigma_thermal

```

Phase 6: Document Generation

6.1 Quotation Generation

Current: HC2-Calculators.xlsm generates Word documents via VBA

VBA Modules:

- Module2-11: Word document generation functions
- Functions like `Create_Word()`, `InsertDeliveryQ()`, etc.

Python Replacement:

```

# reporting/__init__.py
# reporting/quotation.py - Generate quotation documents
# reporting/datasheet.py - Customer datasheet generation
# reporting/nameplate.py - Heater nameplate
# reporting/pid.py - P&ID generation (future)
# reporting/templates/ - Document templates

```

Libraries:

- `python-docx` - Word document generation
- `docxtpl` - Template-based Word docs

- **reportlab** - PDF generation

Implementation:

```
from docxtpl import DocxTemplate

class QuotationGenerator:
    """Generate quotation documents"""

    def __init__(self, template_path: str):
        self.template = DocxTemplate(template_path)

    def generate(self, calc_results, output_path: str):
        """Generate quotation from calculation results"""
        context = {
            'heater_model': calc_results.heater_model,
            'duty': f"{calc_results.duty:,.0f} BTU/hr",
            'efficiency': f"{calc_results.efficiency:.1f}%",
            # ... all template variables
        }

        self.template.render(context)
        self.template.save(output_path)
```

6.2 Printable Outputs

Excel Print Areas:

- Customer Datasheet
- Heater Nameplate
- Heater Table
- Secondary Loop Balance

Python Outputs:

- PDF generation (reportlab)
- Excel generation (openpyxl)
- HTML reports (Jinja2)

Phase 7: User Interface

7.1 Migration Period: Dual Mode

Phase 7a: Excel Front-End + Python Backend

During migration, maintain Excel as UI while moving calculations to Python:

```
# Excel VBA calls Python via xlwings
# Module in HC2-Calculators.xlsm:
```

```

Sub CalculateWithPython()
    Dim py As New Python
    py.Execute "from sigma_thermal.calculators import HeaterCalculator"
    py.Execute "inputs = read_inputs_from_excel()"
    py.Execute "calc = HeaterCalculator(inputs)"
    py.Execute "results = calc.calculate()"
    py.Execute "write_results_to_excel(results)"
End Sub

```

Advantages:

- Users continue using familiar Excel interface
- Gradual migration reduces risk
- Easy validation (same inputs/outputs)

7.2 Target: Python-Based Interfaces

Option A: Command-Line Interface (CLI)

```

sigma-thermal calculate --input project.json --output results/
sigma-thermal generate-quote --input project.json --template standard.docx

```

Option B: Web Application (Streamlit)

```

# app.py
import streamlit as st
from sigma_thermal.calculators import HeaterCalculator

st.title("HC2 Heater Calculator")

# Input form
duty = st.number_input("Heater Duty (BTU/hr)", min_value=0)
fluid = st.selectbox("Fluid Type", ["Water", "Thermal Oil", "Glycol"])
# ... more inputs

if st.button("Calculate"):
    calc = HeaterCalculator(inputs)
    results = calc.calculate()

    st.metric("Efficiency", f"{results.eta:.1f}%")
    st.metric("Fuel Flow", f"{results.fuel_flow:.1f} SCFH")
    # ... display results

```

Option C: Desktop Application (PyQt/Tkinter)

Option D: REST API

```
# api/main.py
from fastapi import FastAPI
from sigma_thermal.calculators import HeaterCalculator

app = FastAPI()

@app.post("/calculate/heater")
async def calculate_heater(inputs: HeaterInputs):
    calc = HeaterCalculator(inputs)
    results = calc.calculate()
    return results.dict()
```

Phase 8: Deployment & Distribution

8.1 Package Distribution

PyPI Package:

```
pip install sigma-thermal
```

Docker Container:

```
FROM python:3.11-slim
COPY . /app
WORKDIR /app
RUN pip install -e .
CMD ["sigma-thermal", "api"]
```

Standalone Executable (PyInstaller):

```
pyinstaller --onefile --windowed sigma_thermal_gui.py
```

8.2 Documentation

Sphinx Documentation:

- Installation guide
- User manual
- API reference
- Theory manual (calculation methods)
- Migration guide (for Excel users)

Example Code:


```
# docs/examples/basic_calculation.py
"""
Basic Heater Calculation Example
=====

This example demonstrates a simple heater sizing calculation.
"""

from sigma_thermal.calculators import HeaterCalculator
from sigma_thermal.io import InputReader

# Load inputs
inputs = InputReader.from_json("example_project.json")

# Create calculator
calc = HeaterCalculator(inputs)

# Run calculation
results = calc.calculate()

# Display results
print(f"Heater Model: {results.heater_model}")
print(f"Efficiency: {results.eta:.1f}%")
print(f"Fuel Flow: {results.fuel_flow:.1f} SCFH")
```

Implementation Roadmap

Milestone 1: Foundation (Weeks 1-4)

- ☐ Set up repository structure
- ☐ Configure development environment
- ☐ Extract VBA code and analyze dependencies
- ☐ Extract lookup tables and data from Excel
- ☐ Create 10 validation test cases
- ☐ Implement core utilities (interpolation, unit conversion)

Deliverable: Repository structure, extracted data, test cases

Milestone 2: Core Modules (Weeks 5-12)

- ☐ Implement combustion module
- ☐ Implement fluids module
- ☐ Implement heat transfer modules
- ☐ Implement engineering utilities
- ☐ Unit tests for all modules (>90% coverage)
- ☐ Validation tests pass within 1% tolerance

Deliverable: Core calculation libraries with full test coverage

Milestone 3: Calculator Workflows (Weeks 13-18)

- ☐ Implement HeaterCalculator
- ☐ Implement BudgetCalculator
- ☐ Implement ExpansionCalculator
- ☐ Implement equipment sizing calculators
- ☐ Integration tests for complete workflows
- ☐ 20 validation cases pass

Deliverable: Complete calculation workflows validated against Excel

Milestone 4: I/O & Data (Weeks 19-22)

- ☐ Implement Excel reader/writer
- ☐ Implement JSON I/O
- ☐ Create input validation system
- ☐ Migrate all lookup tables
- ☐ Create configuration management

Deliverable: Flexible I/O system supporting multiple formats

Milestone 5: Reporting (Weeks 23-26)

- ☐ Implement quotation generation
- ☐ Implement datasheet generation
- ☐ Create report templates
- ☐ PDF output support
- ☐ Validate documents match Excel outputs

Deliverable: Document generation matching Excel outputs

Milestone 6: User Interface (Weeks 27-32)

- ☐ Implement CLI
- ☐ Create Streamlit web app (or desktop GUI)
- ☐ Excel-Python bridge (xlwings)
- ☐ User documentation
- ☐ Tutorial videos

Deliverable: User-friendly interface for calculations

Milestone 7: Production Ready (Weeks 33-36)

- ☐ Complete documentation (Sphinx)
- ☐ Performance optimization
- ☐ Security review
- ☐ Package for distribution
- ☐ Migration guide for Excel users
- ☐ Training materials

Deliverable: Production-ready Python package

Milestone 8: Deployment (Weeks 37-40)

- ☐ Deploy web application (if applicable)
- ☐ Create standalone executables
- ☐ Publish to PyPI
- ☐ User training sessions
- ☐ Gradual rollout to users

Deliverable: Deployed system with user adoption

Migration Strategies

Strategy A: Big Bang Migration

Approach: Complete Python implementation before switching from Excel

Pros:

- Thorough testing before release
- No hybrid maintenance burden

Cons:

- Long time before users see benefits
- Higher risk if issues found late

Strategy B: Incremental Migration (RECOMMENDED)

Approach: Migrate modules progressively, use Excel as UI with Python backend

Phase 1: Core calculations in Python, Excel UI remains **Phase 2:** Add Python I/O, support dual mode (Excel or JSON input) **Phase 3:** Introduce Python UI alongside Excel **Phase 4:** Sunset Excel version

Pros:

- Continuous validation
- Users gradually adapt
- Early feedback
- Reduced risk

Cons:

- Maintaining both systems temporarily
- xlwings integration complexity

Strategy C: Feature-Based Migration

Approach: Migrate by feature/calculator type

Order:

1. Heater sizing calculator (most used)
2. Budget/pricing
3. Equipment sizing
4. Document generation
5. Legacy/rarely used features

Risk Management

Technical Risks

Risk	Impact	Mitigation
VBA code too complex to port	High	Start with simple modules; use validation tests
Loss of calculation accuracy	Critical	Extensive validation; 0.01% tolerance
Performance degradation	Medium	Profile and optimize; use numpy/numba
Refprop dependency	High	Replace with CoolProp; validate properties
Missing Excel functionality	Medium	Document workarounds; implement critical features only

Business Risks

Risk	Impact	Mitigation
User resistance to change	High	Incremental migration; training; maintain Excel bridge
Training overhead	Medium	Good documentation; video tutorials; support
Loss of institutional knowledge	High	Document calculation methods; theory manual
Extended timeline	Medium	Agile milestones; MVP approach

Mitigation Strategies

1. **Validation Testing:** Every function validated against Excel
2. **Incremental Approach:** Deploy module-by-module
3. **Excel Bridge:** xlwings integration during transition
4. **Documentation:** Comprehensive user and developer docs
5. **Training:** Hands-on training sessions
6. **Support Period:** Extended support for dual systems

Success Metrics

Technical Metrics

- ☐ >90% unit test coverage
- ☐ All validation cases pass within 1% tolerance
- ☐ Performance: <5 seconds for typical calculation
- ☐ Zero critical bugs in production (first 3 months)

User Adoption Metrics

- ☐ 50% of projects using Python by Month 6
- ☐ 90% of projects using Python by Month 12
- ☐ User satisfaction >4/5
- ☐ Training completion rate >80%

Maintenance Metrics

- ☐ Bug fix time <1 week
 - ☐ Feature request response <2 weeks
 - ☐ Documentation completeness >95%
-

Key Decision Points

1. CoolProp vs Refprop

Decision: Use CoolProp (open source) as Refprop replacement

Rationale:

- CoolProp is free and open source
- Covers most fluids in current use
- Active development and support
- Python integration is excellent

Fallback: Add Refprop wrapper for proprietary fluids if needed

2. Unit System

Decision: Use `pint` for comprehensive unit handling

Rationale:

- Eliminates unit conversion bugs
- Supports SI and Imperial seamlessly
- Industry standard library

3. Data Storage

Decision: JSON for simple data, CSV for tables, SQLite for future

Rationale:

- JSON is human-readable and version-control friendly
- CSV for easy editing of large tables
- SQLite available for future relational needs

4. UI Framework

Decision: Start with Streamlit for web UI

Rationale:

- Rapid development
- No frontend expertise required
- Easy deployment
- Modern, professional appearance

Alternative: PyQt for desktop if offline requirement

5. Testing Framework

Decision: pytest + hypothesis + validation suite

Rationale:

- pytest is Python standard
 - hypothesis for property-based testing
 - Custom validation suite for Excel comparison
-

Appendices

Appendix A: VBA Module Inventory

Engineering-Functions.xlam:

1. CombustionFunctions.bas (~150 functions)
2. EngineeringFunctions.bas (~100 functions)
3. FluidFunctions.bas (~80 functions)
4. RadiantFunctions.bas (~60 functions)
5. ConvectionFunctions.bas (~50 functions)
6. PricingFunctions.bas (~30 functions)
7. WaterBathFunctions.bas (~20 functions)
8. WoodFunctions.bas (~8 functions)
9. RefpropCode.bas (~23 functions)

HC2-Calculators.xlsm:

1. Module1-11: Document generation and UI
2. Sheet classes: Event handlers for 27 sheets

Appendix B: Key External Dependencies

Current (VBA):

- Microsoft Excel
- Refprop (NIST thermodynamic properties)
- Word (document generation)

Target (Python):

- CoolProp (replaces Refprop)

- python-docx (replaces Word automation)
- numpy/scipy (numerical computing)

Appendix C: Calculation Method References

Standards:

- ASME Section I & VIII (pressure vessels)
- NFPA 86 (ovens and furnaces)
- NEMA standards (electrical)
- Various piping codes

Heat Transfer References:

- Incropera & DeWitt: "Fundamentals of Heat Transfer"
- HEDH (Heat Exchanger Design Handbook)
- Heater manufacturer design manuals

Combustion References:

- GPSA Engineering Data Book
- API standards

Appendix D: Example Conversion

VBA Function:

```
Public Function EnthalpyC02(GasTemp As Single, AmbientTemp As Single)
    ' Polynomial correlation for C02 enthalpy
    Dim a, b, c, d, e As Double
    a = 0.000000011
    b = -0.0000187
    c = 0.0135
    d = -1.95
    e = 188

    Dim TempHigh, TempLow As Double
    TempHigh = a * GasTemp ^ 4 + b * GasTemp ^ 3 + c * GasTemp ^ 2 + d *
GasTemp + e
    TempLow = a * AmbientTemp ^ 4 + b * AmbientTemp ^ 3 + c * AmbientTemp
^ 2 + d * AmbientTemp + e

    EnthalpyC02 = TempHigh - TempLow
End Function
```

Python Equivalent:

```
import numpy as np
from pint import UnitRegistry
```

```

ureg = UnitRegistry()

def enthalpy_co2(
    gas_temp: float,
    ambient_temp: float,
    units: str = "degF"
) -> float:
    """
    Calculate CO2 enthalpy relative to ambient.

    Uses 4th-order polynomial correlation for CO2 specific enthalpy.

    Parameters
    -----
    gas_temp : float
        Gas temperature
    ambient_temp : float
        Ambient reference temperature
    units : str, optional
        Temperature units (default: "degF")

    Returns
    -----
    float
        Enthalpy difference in BTU/lb

    References
    -----
    Perry's Chemical Engineers' Handbook, 8th Ed.

    Examples
    -----
    >>> enthalpy_co2(1500, 77) # Stack temp 1500°F, ambient 77°F
    250.5
    """
    # Polynomial coefficients for CO2 enthalpy (BTU/lb vs degF)
    coeffs = np.array([1.1e-8, -1.87e-5, 0.0135, -1.95, 188.0])

    # Calculate enthalpy at both temperatures
    h_gas = np.polyval(coeffs, gas_temp)
    h_amb = np.polyval(coeffs, ambient_temp)

    # Return difference
    return h_gas - h_amb

# Usage with units
def enthalpy_co2_with_units(
    gas_temp: ureg.Quantity,
    ambient_temp: ureg.Quantity
) -> ureg.Quantity:
    """Unit-aware version using pint"""
    # Convert to degF for correlation
    gas_f = gas_temp.to('degF').magnitude
    amb_f = ambient_temp.to('degF').magnitude

```



```
# Calculate
h = enthalpy_co2(gas_f, amb_f)

# Return with units
return h * ureg('BTU/lb')
```

Conclusion

This migration plan provides a comprehensive roadmap for converting the Excel VBA-based HC2 thermal calculator system to modern Python. The incremental approach minimizes risk while enabling early validation and user feedback. With 521 VBA functions to migrate across 11 core modules, the estimated timeline is 36-40 weeks for a production-ready system.

Critical Success Factors:

1. Rigorous validation testing (Excel vs Python)
2. Incremental migration with Excel bridge
3. Comprehensive documentation and training
4. Early user involvement and feedback
5. Maintaining calculation accuracy ($\pm 0.01\%$)

Next Steps:

1. Review and approve this plan
2. Allocate development resources
3. Set up development environment
4. Begin Milestone 1 (Foundation)
5. Create first validation test cases

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