REopt Lite Geothermal Heat Pump Model Design Requirements Document

Dan Olis, Kate Anderson, Bill Becker

December 22, 2020

Table of Contents

1 Introduction 2
1.1 Purpose 2
1.2 Scope 2
1.3 Acronyms 2
1.4 Applicable Documents 2
2 General Description 3
2.1 Product Perspective 3
2.2 Product Functions 3
2.3 Assumptions and Dependencies 3
3 Requirements 4
3.1 Capabilities 4
3.2 Additional Requirements 5
3.3 Not Currently in Scope 5
3.4 Assumptions 5
3.5 Inputs 6
3.6 Outputs 8
3.7 Documentation 8

List of Figures

Figure 1. Diagram of GHP module perspective (in bold) in existing REopt Lite web tool 3

List of Tables

Table 1. GHP Module Inputs. 6
Table 2. GHP Module Outputs. 8

1 Introduction

1.1 Purpose

This is the Design Requirements documentation for the geothermal heat pump (GHP) module being added to the existing REopt Lite web tool. This document describes the purpose, users, and functional requirements to which the modified web tool shall conform. This document will be revised, as required, throughout the development phase with consensus between the Department of Energy (DOE) Geothermal Technologies Office (GTO) and NREL. It will inform the NREL development team of the REopt Lite GHP tool's requirements.

1.2 Scope

- GHP module to be added to existing REopt Lite web tool
- Module will allow techno-economic optimization analysis of GHP alone or in combination with the other distributed energy resources (DER) options already existing in REopt Lite, including PV, wind, battery storage, thermal energy storage, and combined heat and power (CHP).
- Module generates the economic outlook for GHP and other DER at an existing facility to identify whether the technology may be worth further consideration with more detailed assessment.
- Primary application/emphasis is for commercial to small industrial.
- Expected user expertise level: beginner to expert.

1.3 Acronyms

AOP	Annual operating plan
COP	Coefficient of performance
DER	Distributed energy resources
DOE	Department of Energy
GHP	Geothermal heat pump
GHX	Ground heat exchanger
GTO	Geothermal Technologies Office
NREL	National Renewable Energy Laboratory

1.4 Applicable Documents

- NREL REopt team AOP with DOE Geothermal Technologies Office for implementation of GHP in REopt Lite
- Dylan Cutler, Dan Olis, Emma Elgqvist, Xiangkun Li, Nick Laws, Nick DiOrio, Andy Walker, Kate Anderson. 2017. *REopt: A Platform for Energy System Integration and Optimization*. NREL/TP-7A40-70022. https://www.nrel.gov/docs/fy17osti/70022.pdf
- REopt Lite User Manual. NREL/TP-7A40-70022. https://www.nrel.gov/docs/fy17osti/70022.pdf (https://reopt.nrel.gov/tool/REopt%20Lite%20Web%20Tool%20User%20Manual.pdf)

- NREL.gov Web Standards: https://www.nrel.gov/web-standards/

2 General Description

This section describes the general requirements for the GHP module to provide context for the specific requirements in Section 3.

2.1 Product Perspective

Figure 1 shows in bold the GHP technology module to be added to existing REopt Lite suite of technologies. This document describes only the requirements for the GHP module added under this project.

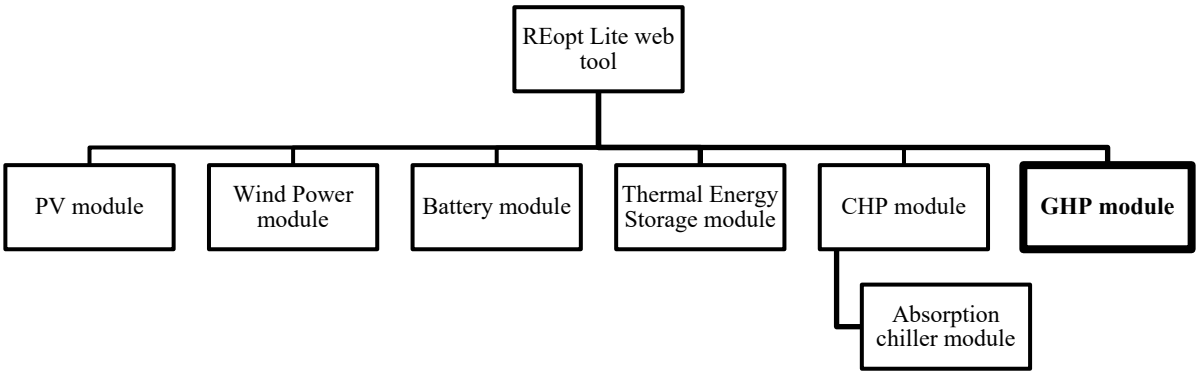

Figure 1. Diagram of GHP module perspective (in bold) in existing REopt Lite web tool

2.2 Product Functions

The GHP module will expand existing REopt Lite capabilities to include techno-economic optimization of GHP systems, either stand alone, or integrated with the other existing technology types, namely solar photovoltaics (PV), wind power, battery energy storage, thermal energy storage, CHP, and absorption chiller. The module will determine if GHP is cost-effective. An external ground heat exchanger (GHX) program, developed by others[1], will be called from REopt Lite to size the GHX system to serve the facility loads. The cost and performance of the GHX will be used in REopt Lite as part of the techno-economic optimization.

2.3 Assumptions and Dependencies

The requirements listed herein are based on the annual operating plan between GTO and NREL, conversations with GTO personnel, and subject matter experts. Based on the complexity of the scope of work, some of the requirements may need to be modified to conform to the budget, schedule, or expectation of reasonable computation time in a web-based tool. If these factors conflict with requirements, this requirements document will be revised upon concurrence between GTO and NREL.

[1] Currently NREL, DOE GTO, and Oak Ridge National Laboratory (ORNL) are in discussions to have ORNL create the GHX model for REopt to call.

3 Requirements

This section describes the specific requirements of the GHP module.

3.1 Capabilities

The GHP module will include the following list of capabilities.

1. The model will identify GHP potential cost-effectiveness, heat pump capacities, GHX size, and GHP impact on utility consumption and costs for a retrofit application.

2. REopt Lite makes a go/no-go decision based on the cost-benefit analysis as to whether GHP is included in the cost-optimal solution. As an option, the user can require GHP in the solution, even if not cost effective, to model the impact on utility costs, life cycle costs, emissions, and the cost-benefit of other DER.

3. Utility consumption impacts, and therefore costs, will be determined on an hourly basis for typical heating and cooling load profiles. Note that in REopt Lite we only model one year of hourly dispatch of DER to serve the user-entered loads. Since ground temperatures of GHX often drift year after year, the heat pump electricity consumption will also change by year. In REopt, we will use a median or average year of return water temperature from the ground loop when estimating the hourly energy consumption of the heat pumps.

4. The GHX and heat pumps will be sized to serve heating and cooling loads of the facility being screened. At a minimum, the screened facility's full heating and full cooling load will be assumed to be served by the GHP. Other intermediary levels of heating and/or cooling load could be considered by the model, either by user option or as default functionality, depending on best-practice guidance from consulting SME's and level of effort.

5. The hourly operation of the GHP is assumed to be fixed by the needs of the cooling and heating loads to be served; for GHP, REopt Lite will not be making dispatch decisions for how and when to operate.

6. If the user selects additional technologies to consider, e.g., PV, battery, and/or CHP, the model determines the size and dispatch of the additional technology options for maximizing economic value.

7. The GHP module will include default design, performance, and cost parameters for the heat pumps and GHX. These parameters will be visible to and modifiable by the user.

8. The GHP module will include default ground thermal properties. These ground property defaults will be visible to and modifiable by the user.

9. The model will be accessible via web interface, application programming interface (API), and open-source software.

10. Heat pump power consumption will be modeled hourly using heat pump performance functions and ground loop water return water temperature from the GHX model.

11. Users that develop a user account can save runs and then compare inputs and outputs for different model scenarios.

12. Detailed cost inputs will be modeled, including utility costs, CAPEX, O&M, incentives, discounting, tax treatments, and depreciation.

13. The impact of utility costs will be determined based on user-selected or defined electricity rate tariffs. Electric rate tariffs can include time of use and tiers in both energy and demand charges.

14. The model will estimate the CO2 emissions of both the base case and the modeled system.

15. Results will include dynamic interactive plots for review of both electric and thermal dispatches with the option for export of time series dispatch to CSV file format.

3.2 Additional Requirements

In addition to the capabilities listed above, the REopt Lite tool must comport to the following requirements after the GHP module is added:

1. Computation time requirement

2. NREL.gov web standards: https://www.nrel.gov/web-standards/

3.3 Not Currently in Scope

The following are not within the scope of requirements for the GHP module, however they will be considered for inclusion as time and budget allow:

1. Optimal determination of how much of the hourly heating and cooling load to be served by GHP

2. Hourly dispatch of GHP

3. Providing a range of system configurations, economic, and technical performance results with one run of REopt Lite

3.4 Assumptions

The following assumptions establish the primary basis of the GHP module design:

1. GHP is installed as a retrofit into a facility with existing central heating and cooling plants.

2. The GHP module does not size nor cost the existing conventional heating plant. There is an existing fuel supply to the existing heating plant and the fuel is costed on a per unit of consumption basis.

3. There is an existing hot water heating distribution loop; the GHP module does not size or cost the heating distribution system. If the heating system is steam, the model does not size or cost a retrofit of the heating loop and heat exchangers to convert from steam to hot water.

4. The GHP module does not size nor cost the existing conventional cooling plant.

5. There is an existing cooling loop served by the existing chiller system; the GHP module does not size or cost the cooling distribution system.

6. Existing heating and cooling loops at the facility remain and are utilized by GHP centralized heat pumps; heat pump units interconnect into the existing heating and cooling loops in the existing central plants.

7. The hourly heating and cooling load profile to be served are model inputs.

8. There is only one heating load and one cooling load to be served by centralized heat and cooling plants; multiple independent heating and cooling systems are not considered.

9. The facility has space to install any selected system. Costs for construction of a building to house a new GHP components (water pumps, controls, heat pumps) are not included.

10. Thermal properties of ground are available or can be approximated to reasonable default values.

11. Default cost assumptions do not vary by region or location.

3.5 Inputs

Inputs specific to the GHP module are described here. General inputs and inputs specific to other technology modules are described in the existing reference cited in section 1.4 of this requirements document.

The REopt Lite user selects technology types (GHP, PV, wind turbine generator, battery, CHP, etc.) to consider in the analysis. Default selections will be provided and help text will guide users in selecting among different technology options appropriate to site loads.

Table 1. GHP Module Inputs.

Variable	Notes
Typical heating load (MMBtu/hr)	Model requires hourly profile for a typical year. User will enter an hourly fuel consumption profile for heating load. Without hourly data, the user will enter annual or monthly heating or fuel consumption for heating loads and select a representative building from DOE's Commercial Reference Buildings list to

	approximate an hourly profile. This input is used both by REopt Lite model and the external GHX model provided by others.
Typical cooling load (ton)	An hourly cooling load profile is required. User will enter an hourly cooling profile. Without hourly data, the user will enter annual or monthly cooling thermal load and select a representative building from DOE's Commercial Reference Buildings list to approximate an hourly profile. This input is used both by REopt Lite model and the external GHX model provided by others.
Heating plant fuel type	Drop-down selection: natural gas, biogas, propane, and diesel
Fuel cost of existing heating plant ($/MMBTU)	User can enter a single value or unit cost by month. (REopt Lite already includes complex electricity cost tariff modeling).
Existing heating system boiler efficiency	This is the efficiency of the existing heating system boiler. Default is 80%.
Existing chiller plant average COP	User entry. Default value will be based on the assumed size of the chiller plant based on peak of the cooling load entered by the user.
Force GHP into solution	Input button option selection (yes/no) to force GHP into the solution even if it is not found to be cost-effective.
Total installed cost for heating heat pump ($/ton)	Default value provided.
Total installed cost for cooling heat pump ($/ton)	Default value provided.
Total installed cost for GHX ($/ft)	Default value provided.
O&M Cost ($/ton)	Fixed O&M cost. Default 0. Applied separately to both the heating heat pump and the cooling heat pump. The default is 0 since we don't currently include O&M costs for existing cooling and heating plant so adding O&M for GHP will disadvantage it inaccurately.
GHP performance (COP) function	Default heat pump performance map(s) will be provided that characterize the heat pump coefficient of performance as a function of entering water temperature. This input is sent to the external GHX model provided by others.
GHX engineering parameters	Defaults for required inputs to the GHX model will be provided, including pipe diameter, thickness, and thermal conductivity; heat transfer fluid properties; borehole depth and spacing; grout thermal conductivity; etc. These inputs are sent to the external GHX model provided by others.
Ground properties	Defaults for required inputs to the GHX model will be provided, including thermal conductivity, density, specific heat, temperature, etc. These inputs are sent to the external GHX model provided by others.
Capital cost incentives - Total percentage-based incentive (%)	Default is 0.
Capital cost incentives- Total rebate ($/ton)	Default is 0. We will explore incentive structures for GHP on DSIRE database to see if this or other incentive constructs would be useful to include.

Production based incentives ($/kWh or $/MMBTU)	Default is 0.
Federal investment tax credit (ITC)	Default is current federal incentive by technology.
MACRS Schedule	This is the modified accelerated cost recovery system, a US Internal Revenue Service term for classifying assets for depreciation for tax purposes. Default is the federal schedule for the appropriate technology.

3.6 Outputs

Outputs specific to the GHP module are described here. General outputs and outputs for other technology modules are described in the existing reference cited in section 1.4 of this requirements document.

Table 2. GHP Module Outputs.

Variable	Notes
Determination of economic viability of GHP	If cost effective, size of components, costs, and economic and performance parameters for GHP system are reported. Details of each are listed in this table below.
GHP heating unit size (tons) GHP cooling unit size (tons)	Rated capacity of heat pumps. These are determined by the GHX external model developed by others.
GHX size (feet)	Total lineal feet of the ground loop heat exchanger's vertical wells. This is determined by the GHX external model developed by others.
Economic parameters	All the economic parameters currently included in REopt Lite will be reported for the base case and the optimal technology solution, including lifecycle costs, net present value, utility costs, capital costs, and maintenance costs.
Hourly and annual total electricity consumption for GHP heating unit	These are determined by the GHX external model developed by others.
Hourly and annual total electricity consumption for GHP cooling unit	These are determined by the GHX external model developed by others.
Hourly and annual total electricity consumption for GHX water recirculating pump(s)	These are determined by the GHX external model developed by others.
Annual avoided boiler plant fuel (MMBtu)	Heating plant displaced fuel consumption due to conversion to GHP
CO2 emissions	Base case versus the optimal case

3.7 Documentation

In addition to a functional GHP module added to the REopt Lite web tool, the following documentation will be generated:

Document	Description
User Manual	The existing web manual will be updated to include description and help for the GHP module.