Concepts, Data Sources, and Techniques
Handbook of Energy Modeling Methods

World Energy Projection System (WEPS): District Heat Module

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1. Introduction

District heat is heat that is generated in a centralized location and distributed through a pipeline system and used for residential, commercial, and industrial space heating and water heating. The WEPS District Heat Module projects the amount of district heat generated by region to satisfy the district heat demand projected by the WEPS Residential, Commercial, and Industrial Demand modules. The District Heat Module also calculates the total energy and the energy by fuel consumed for district heat generation and projects regional end-use prices of district heat for the residential, commercial, and industrial sectors. The District Heat Module makes these annual projections for each of the 16 WEPS regions for heat generated from various energy sources (Table 1).

Inputs for the module include distillate fuel prices, residual fuel prices, and natural gas prices from the WEPS Hydrocarbon Supply Module and coal prices from the WEPS Coal Supply Module. Fuel consumption projections serve as inputs to the supply modules, and retail district heat prices serve as inputs to the Residential, Commercial, and Industrial Demand modules.

Table 1. Key variables and categories in the District Heat Module

Index	WEPS region	Fuel	District heat technology	Heat-consuming end-use sectors
1	United States	Distillate	Combined heat-and-power (CHP)	Commercial
2	Canada	Residual fuel	Heat-only boiler	Residential
3	Mexico and Other OECD Americas	Natural gas		Industrial
4	OECD Europe	Coal		
5	Japan	Waste		
6	South Korea	Biomass		
7	Australia and New Zealand	Geothermal		
8	Russia			
9	Other Non-OECD Europe and Eurasia			
10	China			
11	India			
12	Other Non-OECD Asia			
13	Middle East			
14	Africa			
15	Brazil			
16	Other Non-OECD Americas			

Source: U.S. Energy Information Administration, World Energy Projection Model

2. Projecting District Heat Generation

The District Heat Module's main purpose is to estimate district heat generation and the amount of fuel consumed for district heat generation annually by region and fuel type over the projection period. The module uses a stock/flow approach in which new heat generation is added each year as necessary, based on the heat generation requirement from the end-use demand sectors. The module projects fuel use quantities for each WEPS region for distillate, residual fuel, natural gas, coal, waste, biomass, and geothermal.

The module calculates the district heat consumption and heat generation required to fulfill demand for district heat in the residential, commercial, and industrial sectors. Demand can be met by heat generated from combined heat-and-power plants (CHP) in the electric power sector or from heat-only boilers in district heat plants. The module sends total CHP generation requirements for each region and year to the WEPS Electricity Module, which determines the fuels that are used to generate heat from CHP.

After accounting for CHP's contribution to meeting heat demand, the District Heat Module projects the remaining heat generation required and the fuel consumed to generate heat for each region. The module calculates district heat-only generation capacity additions by fuel for each projection year. Based on projected fuel consumption and heat generation, it then determines retail district heat prices. The module exports its fuel consumption and district heat price projections to a common database for use by other WEPS modules.

The module imports and stores data series from outside of WEPS, including discount rates applied to future cash flows, parameters that determine how costs influence utility investors' choices of heat generation technology, and heat generation technology attributes. Attributes include:

- Fuel type
- Non-fuel heat generation costs
- Equipment load factors
- District heat plant lifetimes
- Efficiency of new heat generation plants

The module imports values, such as district heat demand, fuel prices, and carbon prices, from other WEPS modules.

When district heat is distributed to homes and businesses, some heat is lost in the transmission and distribution process. The module estimates historical transmission and distribution losses by year:

$$\text{Transmission \& Distribution Loss Factor} = \frac{\text{Heat Demand Net of CHP Heat Generation (Btu)}}{\text{Heat Generated (Btu)}}$$

Similarly, the module estimates historical generation efficiencies by fuel and year:

$$\text{Consumption-to-generation ratio (inverse of efficiency)} = \frac{\text{Fuel Consumed for Heat Generation (Btu)}}{\text{Heat Generated (Btu)}}$$

The module uses an iterative exponential smoothing algorithm to project the historical values for the transmission-distribution loss factor and consumption-to-generation ratio forward into the projection years. This forecasting method determines future values using a weighted average of historical observations, weighting recent observations more heavily than those in the distant past. The district heat module uses double exponential smoothing, so if a trend is present in the historical data, it will be projected into the future. Parameters estimated by expert judgment determine how the exponential smoothing algorithm weights observations in the recent past relative to observations in the distant past.

For each projection year, we project the required generation by dividing heat demand by the region's transmission and distribution loss factor:

$$\text{Generation Required (Btu)} = \frac{\text{Heat Demand}}{\text{Transmission-Distribution Loss Factor}}$$

From here, the module breaks out total generation required into heat-only generation and CHP generation, using the following algorithm:

1. If total heat demand increases, additional demand is met by CHP rather than heat-only boilers. This assumption reflects that CHP tends to be more efficient than heat-only boilers and that some major district heating regions use policy levers to encourage CHP's role in satisfying overall heat demand.

2. Otherwise, demand is satisfied by CHP and heat-only boilers according to each generation type's historical share.

3. If there is an exogenous target for the share of CHP generation, this must be met. If necessary, this target overrides steps #1 and #2 in the algorithm.

The module then determines how much generation capacity is projected to already exist in the projection year. The module assumes that the rate at which existing generation capacity is retired is the inverse of the plant lifetime assigned to each generation fuel.

3. Simulating Compliance with Clean Energy Targets

The District Heat Module can simulate compliance with analyst-specified minimum or maximum targets for heat generation from specific fuels. For each region, if a generation target is specified, the module first determines whether the target is a single-fuel target or a combined renewable energy target. If it is a combined renewable energy target, the module assumes that the target may be met by a set of fuels; currently, these include biomass and geothermal. A target for a projection year may be specified as a percentage or as an amount in thousand British thermal units (Btu).

When a minimum target is specified and the current projection year is before the target year, the module determines the increment that must be added to the previous projection year's generation percentage or the previous projection year's generation amount to increase fast enough to meet the target.

When a maximum target is specified and the current projection year is before the target year, the module determines the increment that must be removed from the previous projection year's generation percentage or the previous projections year's generation amount to decrease fast enough to meet the target.

If the current projection year is after a minimum target year, the module determines whether any additional capacity is required to ensure that generation remains greater than or equal to the target level. If the target is a combined renewable energy target, the module determines the share of each renewable fuel that will be used to satisfy the target by employing the multinomial logit algorithm described below. The new projected generation is then added to the generation capacity stock.

If the current projection year is after a maximum target year, the module determines whether any capacity should be retired to ensure the generation remains lower than or equal to the target level.

4. Projecting District Heat Capacity and Fuel Consumption

If, after simulating compliance with minimum fuel targets, existing generation capacity is sufficient to meet the current projection year's generation requirements, the District Heat module does not add any new capacity. Rather, it uses two capacity categories to satisfy generation required:

- Remaining capacity, which is capacity added during the historical period and existing in the first projection year
- Additional capacity, which is capacity added during the projection period but before the current projection year

The module assumes that additional capacity, which is more efficient than remaining capacity, is used first; any generation requirement not met by additional capacity is met by remaining capacity. It further assumes that total generation equals required generation and that fuel shares of generation equal the fuel shares of existing capacity.

If heat generation from a particular fuel exceeds a maximum target, the module brings generation into compliance by simulating the retirement of some generation capacity specific to that fuel. Retirements are projected to first occur among the equipment stock that was added during the historical period, prior to the first projection year.

If the projected existing generation capacity is not sufficient to meet the current projection year's generation requirements, the module adds new capacity. It uses a multinomial logit algorithm to determine fuel shares of new capacity. For each fuel, the module calculates the levelized cost of the corresponding fuel type using non-fuel costs, discount rates, learning indices, and fuel prices. These levelized costs are converted into a *technology weight* using an assumed logit parameter *Lambda*:

$$\text{Technology Weight} = (\text{Levelized Cost})^{-\text{Lambda}}$$

The module projects fuel shares by dividing each technology weight by the total weight for all fuels. To project new generation capacity by fuel, it then multiplies the fuel shares by the total new generation required. New generation capacity is added to the additional capacity stock. In years where new generation capacity is added, the module assumes that both additional and remaining capacity stock are fully utilized, and that total generation is equal to the sum of generation from new and existing capacity for each fuel.

To project fuel consumption, the module uses two sets of fuel consumption-to-generation ratios, known as efficiencies. It multiplies the district heat generation from remaining generating capacity (not added or retired during the projection period) by the historical consumption-to-generation ratio, which we estimate using data from the most recent historical year. This remaining capacity is assumed to be less efficient than the new capacity added during the projection period.

The module projects fuel consumed by the additional generating capacity (added during the projection period) by multiplying the projected consumption-to-generation ratio for new generation in the projection year by the projected amount of district heat generated for the projection year:

$$\text{Fuel Consumption (Btu)} = \text{Consumption-to-Generation Ratio} \times \text{Generation (Btu)}$$

Finally, the module projects retail district heat prices for the residential, commercial, and industrial sectors. It calculates the total fuel cost per Btu by multiplying the fuel price from the latest WEPS iteration by the projected fuel consumption, then dividing by total district heat generated. The function adds a heat price adder, which is calculated based on historical fuel costs and heat prices, to the fuel cost.

Heat Price (\$/Btu) =

$$\frac{\sum_{\text{Fuels}} (\text{Fuel Consumption to Generate Heat (Btu)} \times \text{Fuel Price (\$/Btu)})}{\text{Heat Generated (Btu)}} + \text{Heat Price Adder (\$/Btu)}$$

After projecting consumption, generation, and prices, the module writes the projections to a WEPS common database for use in future iterations of WEPS. These output data series include projections of fuel consumption by fuel type in the district heat sector as well as end-use sector retail prices of district heat.