Table A-11.C. Technical implementation considerations for electrical resistance heating

Data requirements	Site-specific data for technology evaluation	Site size and soil characteristics	Soil electrical resistivity, buried debris, and subsurface utilities. Soil permeability, total organic carbon. Soil permeability, soil conductivity, plasticity (classification), bulk density, heat capacity, total organic carbon, site boundary—problems of scale.
		Groundwater characteristics	Hydraulic conductivity, gradient, geochemistry (buffering capacity).
		LNAPL characteristics	Chemical properties (vapor pressure, boiling point, octanol-water partitioning coefficient, viscosity, etc.), concentrations.
		LNAPL depth	Shallow contaminants may need to implement surface cover/cap.
		LNAPL location	Open area or under building, near utilities.
		Off-gas treatment	Vapor phase granular activated carbon is generally used for small sites, thermal oxidation can be used at larger sites. Concentrations of nontarget contaminants may affect loading and vapor technology selection.
	Bench-scale testing	Generally only required for high boiling point hydrocarbons.	
		Soil characteristics	Permeability, moisture, classification.
		Heating effectiveness/ mass recovery	Relationship between heating time, steam production and mass recovery.
		Groundwater geochemistry	Not required.
	Pilot-scale testing	Not generally required. Normally estimated via modeling by the thermal vendor.	
		Heating rate	Time needed to reach optimal/maximum temperature in treatment zone.
		Water injection	Possibility of water addition into the treatment zone to maintain conductivity of soil.
		Safety concerns	High voltage, electrical connections, buried metal objects, vapor/ lower explosive limit, community concerns.
	Full-scale design	Power application/ consumption	Power application and consumption are generally estimated by numerical modeling performed by the thermal vendor. Secure sufficient power supply/transformer.
		Steam generation	Record amount of in situ steam generated by subsurface heating to determine energy removal during the remedy.
		Off-gas treatment	Selection of off-gas treatment dependent upon contaminant type and mass, regulations, etc.
		Heating rate	Time needed to reach optimal/maximum temperature in treatment zone (and compare to estimates by the thermal vendor).
		Water injection	Possibility of water addition into the treatment zone to maintain conductivity of soil.
		Safety concerns	High voltage, electrical connections, buried metal objects, vapor/ lower explosive limit.
	Performance metrics	Groundwater concentrations	Groundwater concentrations can be expected to increase as the site is heated, and then decrease as the LNAPL is removed.
		Temperature in treatment zone	How quickly maximum/optimum temperature was reached and how long it was held constant. Ensure that the target treatment temperature is reached or exceeded throughout the treatment area.
		Temperature outside of treatment zone	Determine extent of heating at edge of treatment zone.
		Mass removal rates	Removal rates are expected to increase as the site is heated, then decrease as the amount of mass remaining in the treatment area diminishes. Monitor for vapor, extracted water and recovered NAPL.
		Off-gas concentrations	Monitored for compliance with permits.
Modeling tools/applicable models		The thermal vendors will perform the required modeling.	

Further information	Thermal Remediation Services, Inc. n.d. “LNAPL Remediation Using Electrical Resistance Heating.” www.thermalrs.com/technology/whitePapers/ERH%20NAPL%20OH%20113009%20acf.pdf
	Thermal Remediation Services, Inc. n.d. “Three-Phase Heating? Six-Phase Heating? Which Is Better?” www.thermalrs.com/technology/whitePapers/ThreePhase_vs_SixPhase.pdf
	USACE. 2009. Engineering and Design: In Situ Thermal Remediation. EM-1110-1-4015. https://clu-in.org/download/techfocus/thermal/EM_1110-1-4015.pdf