The Director General

Maisons-Alfort, 22 August 2011

OPINION
of the French Agency for Food, Environmental and Occupational Health & Safety

on the analysis of the health risks related to the installation, operation, maintenance and abandonment of renewable energy recovery systems (geothermal facilities, solar panels and wind turbines) in catchment protection zones for water intended for human consumption

1. REVIEW OF THE REQUEST

The French Food Safety Agency (AFSSA), which was merged into the French Agency for Food, Environmental and Occupational Health & Safety (ANSES) on 1 July 2010, received a solicited request on 22 February 2010 from the French Directorate General for Health (DGS) for an assessment of the health risks related to the installation, operation, maintenance and abandonment of renewable energy recovery systems in catchment protection zones (CPZs) used for supplying water intended for human consumption (WIHC).

2. BACKGROUND AND PURPOSE OF THE REQUEST

The French Planning Act No. 2005-781 (POPE Act) of 13 July 2005 which set out guidelines for energy policy, transposing Directive 2001/77/EC of 27 September 2001[1] into French law, together with the Grenelle Environment Round Table laws, advocate increasing the share of renewable energy in final energy consumption. Within this context, the French Regional Health Agencies (ARSs) are increasingly being petitioned by developers and communities to install renewable energy recovery systems in the CPZs for WIHC because of the easements created here which, in some cases, may prohibit, suppress or limit the development of certain other activities, especially agricultural.

[1] *Directive 2009/28/EC of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC.*

The main renewable energy sources used to produce electricity or heat (for heating and/or domestic hot water production), that may pose a risk to water resources intended for the production of WIHC are wind, solar and geothermal energy. The expert appraisal did not address the risks related to hydraulic energy, previously dealt with by another working group[2]; shallow geothermal energy (Canadian wells or Provençal wells) only involving superficial excavation of the ground; aerothermal energy which does not require excavation of the soil at all; stimulated deep geothermal energy (EGS – Enhanced Geothermal System) which is only at the experimental stage in France; biomass production facilities which have no specific impact on water resources; individual solar thermal installations primarily installed on buildings and industrial thermodynamic devices not currently found in mainland France.

The expert appraisal conducted within the framework of this Request considered only the risks to underground water resources for the production of WIHC because the land included in the CPZs plays an important role in protecting water quality by retaining or degrading pollutants and requires *de facto* a great expanse. In the case of surface water intakes, the protection zones are only intended to secure the water supply by ensuring that surface flows can reach them quickly. Moreover, the CPZs of surface water intakes, which are small in size and comprised of narrow strips of land along water courses or bodies, and are often in flood zones or fluctuation zones of water bodies, are less suitable for the installation of renewable energy recovery systems.

The objective of this work is:

- to analyse the main health risks associated with the installation, operation, maintenance and abandonment of various renewable energy recovery systems (geothermal, solar, wind) in different catchment protection zones,
- to propose, as an example, measures for managing the critical points identified that should be implemented and monitored when the installation of renewable energy recovery systems is authorised.

The CPZs aim to protect water resources from pollution (mainly occasional and accidental) that can render the water unfit for consumption. Three areas can be established[3]:

- a mandatory immediate protection zone (ImPZ), generally an area of several hundred square metres, which serves to prevent the deterioration of withdrawal structures and to avoid spills or seepage of pollutants and microbiological contaminants occurring in or in immediate proximity to the catchment. The land comprising the ImPZ must be acquired outright[4] by the beneficiary of the declaration of public utility (DPU) and should be enclosed, barring exceptions;
- a generally essential inner protection zone (InPZ) of varying extent, which acts as a buffer zone against hazardous activities that should provide sufficient reaction time, in case of pollution. Within this protection area any works, installations, activities,

[2] *AFSSA (2008). "Lignes directrices pour l'installation de turbines hydroélectriques sur des canalisations d'eaux brutes utilisées pour la production d'eaux destinées à la consommation humaine, sur des canalisations d'eaux en cours de traitement et sur des canalisations d'eaux destinées à la consommation humaine."* [Guidelines for the installation of hydroelectric turbines on raw water pipes used for the production of water intended for human consumption, on water pipes during treatment, and on pipes used for water intended for human consumption,] Report No. 2008-SA-0013.

[3] *DGS (Mai 2008). "Eau et santé - Guide technique - Protection des captages d'eau - Acteurs et stratégies."* [Water and Health – Technical Guide - Protection of water catchment zones – Stakeholders and strategies] French Ministry of Health and Sports.

[4] *When these lands are under the domain of the State, they should only be subject to a management agreement pursuant to the State-owned property code.*

disposals, structures, facilities or land uses that may lead to pollution that renders the water unfit for human consumption are prohibited.

- an optional outer protection zone (OPZ), corresponding to all or part of the catchment recharge area not covered by the InPZ. Its creation should only be considered when certain activities could cause extensive pollution and when the application of special requirements (restrictions on works, installations, activities, disposals, structures, development or use of lands, which given the nature of the land, can pose a pollution hazard for the water withdrawn) appear likely to lower the risks significantly.

3. Organisation of the expert appraisal

The expert appraisal was carried out in accordance with French Standard NF X 50-110 “Quality in Expert Appraisal Activities - General Requirements of Competence for Expert Appraisals (May 2003)”.

The collective expert appraisal was entrusted to the Working Group (WG) on “Analysis of the health risks related to the installation, operation, maintenance and abandonment of renewable energy recovery systems (geothermal facilities, solar panels and wind turbines) in catchment protection zones for water intended for human consumption” formed on 5 May 2010.

The French Renewable Energies Professional Organisation (SER), the companies CFG Services, EOLE-RES and Électricité de France Énergies Nouvelles (EDF EN), and the French Bureau of Geological and Mining Research (BRGM) were all consulted by the WG.

The analysis of the health risks was carried out based on the following methods:
- Failure Mode, Effects and Criticality Analysis (FMECA),
- Hazard Analysis Critical Control Point (HACCP).

The risks to water resources were characterised by comparing the hazards associated with the impact of installations and/or implementations during the various project phases (design, installation, operation, maintenance and abandonment) and whether or not there are means to control them, with the vulnerability of the groundwater. This analysis considered data from the literature and the contents of the application dossiers for the installation of renewable energy recovery systems in CPZs intended for the production of WIHC received by the ARSs and forwarded to ANSES by the DGS (31 applications including 14 related to wind, 11 to solar photovoltaic and six to geothermal energy).

The analysis conducted and the conclusions of the Working Group’s examination were adopted by the CES on Water, on 5 July 2011.

4. Analysis and conclusion of the CES on Water

4.1. Impact of renewable energy systems and possible control measures

Geothermal energy

1) Horizontal closed loop and basket geothermal energy systems

Deterioration of the environment as a result of construction works for these systems is limited due to their small scale (small land area and minimal excavation involved) and short duration (about one week).

In the event of low-volume spills or leakage of refrigerant or heat transfer fluids during construction, maintenance or in case of circuit deterioration, refrigerants will evaporate and the glycol portion of the heat transfer fluids will break down in the unsaturated zone of the subsoil. Therefore, use of a water/propylene glycol non-admixed blend or heat transfer fluids included on list "A"[5] should be recommended. In addition, the underground network must be declared.

2) Vertical closed loop geothermal energy systems

Owing to their length, the probes or piles generally reach the underlying groundwater.

Drilling operations and subsequently aging of the probes or piles, may result in contamination of the groundwater by muds and hydrocarbons used for drilling and by seepage of stray water as these systems age. Observing best practices when drilling, and during the implementation, operation and maintenance of probes and piles reduces but does not eliminate the risk of contamination.

Interconnecting different groundwater sources, despite being prohibited, is also possible. There is no means of control for the technology involved in producing probes or piles.

In the event of spills or leakage of heat transfer fluids during construction, maintenance or in case of deterioration of the probes or piles, the volume lost will be low, but there may be little or no degradation of the glycol portion of the fluid, in the absence of a sufficiently thick layer of unsaturated ground. Therefore, use of a water/propylene glycol non-admixed blend or heat transfer fluids included on list "A"[5] is recommended.

It is recommended that the probe or piles be drained, back-filled and sealed according to best practices, during the abandonment phase.

3) Open vertical systems

Open systems are subject to the same potential impacts identified for closed vertical systems, in addition to those related to the fact that they create direct and permanent access to the groundwater during water collection or discharge, except when this is done in the near-surface environment.

[5] Circular DGS/PGE/1.D. No. 942 of 2 July 1985 on heat treatment of water intended for human consumption - Article 16-9 of the Standard Departmental Health Regulation. Circular DGS/PGE/1.D. No. 357 of 2 March 1987 on the updated list of fluids and additives used for heat treatment of water intended for human consumption.

Since these systems can interfere with other structures exploiting the same groundwater source, the government will need to establish a plan for harnessing geothermal energy.

Reinjection of used water into the groundwater leads to local alterations of its physico-chemical and microbiological characteristics (Jaudin 1988[6]; Bonte *et al.* 2011a[7]; Bonte *et al.* 2011b[8]; Sowers *et al.* 2006[9]; Brielmann *et al.* 2009[10]).

Finally, corrosion inhibitors, sequestering compounds and dispersants used to protect structures from corrosion or scale formation, will seep into the groundwater.

Solar photovoltaic energy

On sites with photovoltaic power stations, changes that often have to be made to the site's topography, such as the creation of haul roads, erection of shelters to house the electrical equipment, as well as the area covered by panels, may alter the permeability of the soil and flow conditions for rainwater runoff.

Fires in electrical equipment may lead to the formation of poorly understood combustion by-products. According to Lincot *et al.* (2009), cadmium leakage is limited for cadmium telluride panels in case of fire[11]. It is important that electrical equipment comply with current standards, the shelters they are housed in be able to withstand fire, lightning conductors be installed and ground cover and surrounding vegetation be maintained and its growth curtailed.

Wind energy

Foundations whose depth depends on land features can potentially reach the groundwater (piles or stone columns in areas of low bearing capacity). Geotechnical studies to define the depth of the foundations are not generally conducted before the start of construction, whereas this is necessary.

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[6] Jaudin F. (1988). "Eaux souterraines et pompes à chaleur, guide pour l'utilisation de l'eau souterraine à des fins thermiques." Edition BRGM.

*[7] Bonte M.; Stuyfzand P.J.; Hulsmann A.; Van Beelen P. (2011a). "Underground thermal energy storage: environmental risks and policy developments in the Netherlands and European Union." Ecology and Society **16**(1): art22.*

*[8] Bonte M.; Stuyfzand P.J.; Van den berg G.A.; Hijnen W.A.M. (2011b). "Effects of aquifer thermal energy storage on groundwater quality and the consequences for drinking water production: a case study from the Netherlands." Water Science & Technology **63**(9): 1922-1931.*

[9] Sowers L.; York K.P.; Stiles L. (2006). "Impact of thermal buildup on groundwater chemistry and aquifer microbes." Unpublished manuscript: http://intraweb.stockton.edu/eyos/energy_studies/content/docs/FINAL_PRESENTATIONS/4A-5.pdf.

*[10] Brielmann H.; Griebler C.; Schmidt S.I.; Michel R.; Lueders T. (2009). "Effects of thermal energy discharge on shallow groundwater ecosystems." FEMS Microbiology Ecology **68**(3): 273-286.*

[11] Lincot D.; Gaucher R.; Alsema E.; Million A.; Jäger-Waldau A. (2009). "Aspects environnementaux, de santé et de sécurité des systèmes photovoltaïques de First Solar contenant du tellurure de cadmium." Report produced under the authority of the French Ministry for Ecology, Energy, Sustainable Development and the Sea.

Large volumes of oil (up to 700 L) may be used for rotor lubrication, although the nacelle serves as a retention tank.

Because of their height, wind turbines are exposed to lightning, and are therefore fitted with lightning conductors.

During decommissioning, only the above-ground equipment, the upper part of the concrete block and the cables near the turbines and the electrical equipment (10 m radius of the installations) are removed from the soil.

4.2. Vulnerability of groundwater in the CPZs

Vulnerability depends on the type of groundwater:

1. Confined and semi-confined groundwater: their impermeable or semi-impermeable cap provides protection against seepage of most contaminants from the moment this cap establishes continuity. This protection is particularly effective firstly, if this cap is thick and secondly, if the groundwater has a high hydraulic load. However, in the case of semi-confined groundwater, phenomena of drainage, natural or induced by the use of catchments, which can promote the seepage of certain compounds, should not be overlooked.
2. Unconfined groundwater: the unsaturated zone (soil and part of the aquifer located above the groundwater) is an area of retention and degradation for many contaminants. The thickness of this unsaturated zone, its geological composition and especially its clay content, and whether or not the land it is part of is fractured, will determine this zone's ability to retain contaminants.

As a result, groundwater is much less vulnerable when its piezometric surface during high water periods is deep and the permeability of the unsaturated zone is low.

For unconfined groundwater, four levels of vulnerability, in descending order, have been identified:

- shallow groundwater with a piezometric surface less than 10 m deep in permeable soil,
- groundwater with a piezometric surface more than 10 m deep in permeable soil,
- groundwater with a piezometric surface less than 10 m deep but in semi-permeable soil
- groundwater with a piezometric surface more than 10 m deep and in semi-permeable soil

Given the heterogeneity in karst environments, installation projects for renewable energy recovery systems should include a vulnerability study of the sector concerned, paying specific attention to:

- the existence or absence of a protective cap,
- the density of seepage zones, the amount of runoff water, etc.

4.3. Conclusion and recommendations

The CES on Water advises that:

1) The risks of degradation of the groundwater quality, related to the installation of renewable energy recovery systems in CPZs, are ascertained from a comparison of the inherent hazards in various phases of the project (design, installation, operation, maintenance, abandonment) and whether there are means for managing them, with the intrinsic vulnerability of the groundwater being exploited. The phase of the project that poses the greatest risks to the groundwater determines the overall risk associated with the installation of a system.

The risk described below relates to the overall risk of degradation of groundwater quality.

2) In the ImPZ, the risk related to the installation of renewable energy recovery systems is considered to be high due to the close proximity of the installations to be built with the catchment structures for WIHC and access to this zone by people unqualified in matters of WIHC. In addition, with regard to regulatory provisions relating to CPZs, the initiation of new activities outside of those explicitly authorised in the DPU is prohibited and, because of the risk mentioned, the installation of renewable energy systems in the ImPZ of a catchment should not be among the authorised activities.

3) The risk related to installing renewable energy recovery systems in the InPZ is outlined in detail in the table in the annex.

The risk related to the installation of horizontal closed loop and basket geothermal systems is considered to be insignificant, low or moderate, depending on the vulnerability of the groundwater, because these systems are shallow and will not be located in the groundwater to be collected.

The risk related to the installation of vertical closed loop geothermal systems is considered to be high with unconfined groundwater because there is no guarantee of a complete seal between the probes or the piles and the soil, nor that the systems will age well and that stray water will not seep along the probes or the piles. However, the risk is considered to be insignificant with confined or semi-confined groundwater, provided that a clay-like cap is maintained between the cemented base of the probe or the piles and the underlying groundwater in order to keep the latter under pressure (cemented base of the probes or piles more than 3 m above the base of the impermeable groundwater cap).

Concerning geothermal doublets (vertical open-loop) and irrespective of groundwater vulnerability, the risk related to their installation in InPZs is considered to be high.

The risk related to solar photovoltaic installations is considered to be low or insignificant, except in permeable environments in zones where the groundwater is unconfined and shallow (<10 m).

For wind turbine installations, the risk is considered to be:

- insignificant for confined or semi-confined groundwater if the base of their foundations allows for a thickness of at least 3 m from the screen it is resting on;
- high for shallow unconfined groundwater (piezometric surface <10 m);
- low or insignificant for unconfined groundwater with a piezometric surface in high water that lies at a depth of >10 m, provided that the base of the foundation lies at more than 3 m above the high water mark of the groundwater.

Furthermore, in karst areas, the risks related to the installation of renewable energy recovery systems can only be assessed on a case-by-case basis following a vulnerability study conducted by a hydrogeologist licensed in public health[12].

Any accident in a system using renewable energy installed in an InPZ that may have an impact on the quality of the water must be reported immediately to the ARSs. A technical review of the operation of renewable energy recovery systems installed in the InPZ describing the incidents and their possible impact on the quality of the water must be provided to the ARSs annually.

4) In the OPZ, and if management measures are implemented for all the hazards identified, the risks will be lower than in the InPZ due to the distance of the system from the water intake point. In addition, with regard to regulatory provisions relating to CPZs, the installation of renewable energy systems in the OPZ cannot be prohibited but only regulated.

Moreover, it should be emphasised that the pollution risks for aquifers will be the same whether or not they are used for the production of WIHC, hence the need for systems that may be installed outside CPZs to observe the same requirements as for those located within their boundaries, in order to safeguard future resources.

5) When the catchment does not have a defined CPZ, the risk related to the use of renewable energy systems in the recharge area of the capture device can only be assessed on a case-by-case basis with respect to their proximity to the water intake. This assessment must be made by a hydrogeologist licensed in public health[12].

5. THE AGENCY'S CONCLUSION AND RECOMMENDATIONS

The French Agency for Food, Environmental and Occupational Health & Safety adopts the conclusion and recommendations of the CES on Water.

The Director General

Marc MORTUREUX

KEY WORDS

Water intended for human consumption, catchment protection zones for water intended for human consumption, renewable energy recovery systems, geothermal energy, solar photovoltaic, wind.

[12] Ministerial Order of 15 March 2011 on procedures for accreditation, designation and consultation of hydrogeologists for public health.

ANNEX

Table: Results of the risk analysis related to the installation of renewable energy systems in inner protection zones (InPZs)

Vulnerability of the groundwater * / Type of installation	Confined and semi-confined groundwater (no unsaturated zone)	Unconfined groundwater with a piezometric surface <10 m deep in high water		Unconfined groundwater with a piezometric surface >10 m deep in high water	
		Permeable unsaturated zone ($>10^{-4}$ m/s)	Semi-permeable unsaturated zone (from 10^{-7} to 10^{-4} m/s)	Permeable unsaturated zone ($>10^{-4}$ m/s)	Semi-permeable unsaturated zone (from 10^{-7} to 10^{-4} m/s)
Geothermal energy recovery system Closed loop (Baskets and horizontal sensors)	**Insignificant risk**	**Moderate risk**	**Low risk**	**Low risk**	**Low risk**
Geothermal energy recovery system Vertical closed loop (probes and piles)	**Insignificant risk** (if the cemented base of the probes or piles is more than 3 m above the base of the impermeable groundwater cap) **Moderate to high risk** (if the cemented base of the probes or piles is less than 3 m above the base of the impermeable groundwater cap)	**High risk**	**High risk**	**High risk**	**High risk**
Geothermal energy recovery system Vertical open loop	**High risk**	**High risk**	**High risk**	**High risk**	**High risk**
Solar photovoltaic energy installation	**Insignificant risk**	**High risk**	**Low risk**	**Low risk**	**Low risk**
Wind energy installation	**Insignificant risk** (if the base of the foundations is more than 3 m above the base of the impermeable groundwater cap) **Moderate to high risk** (if the base of the foundations is less than 3 m above the base of the impermeable groundwater cap)	**High risk**	**High risk**	**Low risk** (if the base of the foundations is more than 3 m above the highest water levels of the groundwater) **High risk** (if the base of the foundations is less than 3 m above the highest water levels of the groundwater)	**Insignificant risk** (if the base of the foundations is more than 3 m above the highest water levels of the groundwater) **Moderate to high risk** (if the base of the foundations is less than 3 m above the highest water levels of the groundwater)

***Karst environment:** case-by-case vulnerability study.*

French agency for food, environmental and occupational health & safety

Analysis of the health risks related to the installation, operation, maintenance and abandonment of renewable energy recovery systems (geothermal facilities, solar panels and wind turbines) in catchment protection zones for water intended for human consumption

Request No. 2010-SA-0047 [Renewable Energy & Catchment Protection Zones]

Collective Expert REPORT

Expert Committee (CES) on Water

Working Group (WG) on "Analysis of the health risks related to the installation, operation, maintenance and abandonment of renewable energy recovery systems (geothermal facilities, solar panels and wind turbines) in catchment protection zones for water intended for human consumption"

July 2011

Key words
Water intended for human consumption, catchment protection zones for water intended for human consumption, renewable energy recovery systems, geothermal energy, solar photovoltaic, wind.

Introduction of the participants

FOREWORD: the outside experts, CES and WG members, and designated *rapporteurs* are all appointed in a personal capacity, *intuitu personae*, and do not represent their respective parent organisations.

WORKING GROUP

Chairman

Mr Jean CARRÉ
Hydrogeology and hydrogeochemistry
French School of Public Health (EHESP)
Expert Committee on Water

Members

Mr Gilbert ALCAYDÉ
Geology and hydrogeology (Retired)

Mr Olivier CORREC
Materials and heat transfer fluids
Expert Committee on Water
French Scientific and Technical Centre for Building (CSTB)

Ms Sophie HÉRAULT
Regulations concerning water intended for human consumption and implementation of regulatory provisions at the departmental level
French Regional Health Agency of Ile-de-France – Water Service

Mr Pierre LE CANN
Microbiology of water
French School of Public Health (EHESP)
Expert Committee on Water

Mr Jacques MUDRY
Hydrogeology
University of Franche-Comté
Expert Committee on Water

Mr Patrick PEIGNER
Regulations concerning water intended for human consumption and implementation of regulatory provisions at the departmental level
French Regional Health Agency of Pays de la Loire –Local delegation of Maine-et-Loire

ANSES PARTICIPATION

Ms Anne NOVELLI
Coordinator of the Working Group
Water risk assessment unit

OUTSIDE PARTIES CONSULTED BY THE WORKING GROUP

Mses Elsa DEMANGEON and Marion LETTRY, Mr Waël ÉLAMINE
French Renewable Energies Professional Organisation (SER)

Ms Gabrielle NEGREL
Compagnie Française de Géothermie Services (CFG Services)

Ms Marie-Cécile NESSI, Messrs Joseph NICOT-BERENGER, Sébastien ROBERT and Pierre-Guy THEROND
Électricité de France Énergies Nouvelles (EDF EN)

Mses Sonia KOZLOWSKI and Marie FOSSE-PARISIS, Mr DELUBAC
EOLE-RES

Messrs Romain VERNIER and Jean-Claude MARTIN
French Bureau of Geological and Mining Research (BRGM)

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List of abbreviations and acronyms

ADEME: French Agency for Environment and Energy Management.

AFSSA: French Food Safety Agency.

AFSSET: French Agency for Environmental and Occupational Health Safety.

ANSES: French Agency for Food, Environmental and Occupational Health & Safety (following the merger of AFSSA and AFSSET on 1 July 2010).

ARENE: French Regional Agency for the Environment and New Energies.

ARS: French Regional Health Agency.

ATEC: Technical Assessment of the CSTB.

BP: Building permit.

BRGM: French Bureau of Geological and Mining Research.

BSS: Subsoil Database.

CES: Expert Committee.

CETIAT: French Technical Centre for the Heating, Ventilation and Air Conditioning industries.

CFC: Chlorofluorocarbon.

CFG: *Compagnie Française de Géothermie* [French geothermal power company].

CPZ: Catchment protection zones for water intended for human consumption.

CSHPF: French High Council for Public Health.

CSP: French Public Health Code.

CSTB: French Scientific and Technical Centre for Building.

DGS: French Directorate General for Health.

DIREN: French Regional Directorate for the Environment.

DPU: Declaration of Public Utility.

DRE: French Regional Public Works Directorate.

DREAL: French Regional Directorate for the Environment, Land-Use Planning and Housing (merger of the DRIRE, DIREN and DRE).

DRIRE: French Regional Directorate for Industry, Research and the Environment.

EDF EN: EDF Energies Nouvelles.

EGS: Enhanced geothermal system.

FGG: Fluorinated greenhouse gases.

FMECA: Failure Mode, Effects and Criticality Analysis.

GFA: Gross floor area.

HACCP: Hazard analysis critical control point.

HCFC: Hydrochlorofluorocarbon.

HDPE: High density polyethylene.

HFC: Hydrofluorocarbon.

HP: Heat pump.

ICPE: Classified Facility for Protection of the Environment.

ImPZ: Immediate protection zone.

InPZ: Inner protection zone.

MEEDDM: French Ministry of Ecology, Energy, Sustainable Development and the Sea.

MEDDTL: French Ministry of Ecology, Sustainable Development, Transport and Housing.

ODS: Ozone-depleting substance.

OED: Swiss Office for Water and Waste.

OPZ: Outer protection zone.

PE 100: Polyethylene with a hydrostatic resistance classification (Minimum Required Strength or MRS) of 10 MPa at 20°C.

PLU: French local urban planning scheme.

PN: Prior notification.

POPE Act: French planning law establishing energy policy guidelines.

POS: French land use plan.

PTFE: Polytetrafluoroethylene.

RSD: French departmental health regulation.

SER: *Syndicat des énergies renouvelables* [French Renewable Energies Professional Organisation].

SRE: Regional wind scheme.

UTE: *Union technique de l’électricité* [French electrical standards organisation].

WIHC: Water Intended for Human Consumption.

XLPE: Cross-linked polyethylene.

ZDE: Wind development zone.

ZNIEFF: *Zone naturelle d’intérêt écologique, faunistique et floristique* [Zone of ecological interest for fauna and flora].

ZPPAUP: *Zone de protection du patrimoine architectural, urbain et paysager* [Zone of protected urban and rural architectural heritage.

Glossary

Aerothermal energy: use of heat energy from the air. The heat is drawn from the outside air and then transferred by a heat pump into the ambient air of a dwelling or into the hot water supply of a heating system.

Aquifer: body (layer, mass) of permeable rock consisting of a saturated zone (a combination of solid medium and water), sufficiently conductive of groundwater to permit a significant flow of groundwater and collection of appreciable amounts of water. An aquifer also generally contains an unsaturated zone (Castany and Margat 1977).

Basket (vertical spiral heat exchanger): exchanger installed at a depth of from three to 10 m occupying a smaller area than a horizontal collector.

Biomass: biodegradable fraction of products, waste, and residues from biological origin from agriculture (including vegetal and animal substances), forestry and related industries, including fisheries and aquaculture, as well as the biodegradable fraction of industrial and municipal waste (Directive 2009/28/EC of 23 April 2009).

Borehole development: operations designed to improve the permeability of the ground layers in contact with a borehole.

Capture device recharge area: area that receives rain water drawn off by a capture device.

Cold source: environment from which calories are drawn at a low temperature (Béranger 2008).

Collector: term commonly used to refer to the exchanger that extracts energy from the soil, water or air.

Confined groundwater: portion of groundwater whose piezometric surface is higher than the top of the aquifer that contains it.

Drainance: flow of water with a mainly ascending or descending component passing from one aquifer to another through a semi-permeable layer (Castany and Margat 1977).

Enthalpy: quantity whose variation leads to the absorption or production of heat. It is expressed in joules per kilogram (J/kg) (Béranger 2008).

Geothermal energy: energy stored as heat in the soil and subsoil.

Geothermal pile (geothermal foundation): vertical collector (vertical geothermal exchanger) located at the core of building foundations.

Heat pump (HP): thermodynamic device that extracts the heat from one environment (for example, air, water or the ground) to transfer it to another (for example, a home heating system) (NF X 10-970 of January 2011).

Heat source: environment from which calories are released at a high temperature (Béranger 2008).

Horizontal collector (horizontal geothermal exchanger): network of tubes placed at shallow depths (50 to 150 cm). There are variants in which the tubes are placed at two or three levels, incorporated in trenches.

Piezometric level: free water level measured in a structure connected with an aquifer (NF X 10-970 of January 2011).

Piezometric surface: ideal surface representing the distribution of hydraulic heads (piezometric levels) in groundwater.

Piezometer or observation well: well or borehole used for measuring the altimetric level of groundwater at one point of an aquifer to derive the hydraulic head at that point.

Power inverter: electronic device for transforming direct current into alternating current compatible with that of the electricity grid (MEDDTL 2001).

Renewable energy (i.e., energy produced from renewable sources): energy from renewable non-fossil sources, namely: wind, solar, aerothermal, geothermal, hydrothermal, and ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases.
(Directive 2009/28/EC of 23 April 2009).

Saturated zone: subsoil zone in which water completely fills the interstices of the rocks, forming a groundwater body in an aquifer (Castany and Margat 1977).

Solar power tower: tower around which hundreds or thousands of adjustable mirrors (heliostats) are installed that continuously reflect the sun’s rays toward a heat exchanger.

Transformer: device to raise the voltage to the level required for injecting current into the electricity grid.

Unconfined groundwater: free surface groundwater, within an aquifer that contains an unsaturated zone with characteristics similar to those of the saturated zone and a zone of fluctuation (Castany and Margat 1977).

Unsaturated zone: subsoil zone between the ground surface and the surface of an unconfined groundwater source (Castany and Margat 1977).

Vertical collector (vertical geothermal exchanger): very low energy geothermal exchanger that can extract or inject heat in the subsoil. In combination with a heat pump (HP), it can be used for heating or air-conditioning (reversible HP), but also cooling (free cooling) through a heat pump bypass. The vertical geothermal probe consists of a vertical borehole several tens of metres deep, into which is inserted a loop probe connected to a heat pump. A heat transfer fluid circulates inside the tubes, in a closed circuit, collecting or releasing subsoil energy, then transporting and releasing it in the heat pump (NF X 10-970 January 2011).

Wind turbine (or aerogenerator): complete system for converting the mechanical energy of wind into electrical energy. The most common types are horizontal axis wind turbines which comprise a wind tower, a rotor (composed of two or three blades) and a nacelle. The term ‘wind farm’ is generally used to refer to a group of wind turbines (MEEDDM 2010).

Zeotropic mixture: mixture in which the temperature varies during a change in state (condensation, evaporation).

1 Introduction

1.1 Review of the request

The French Food Safety Agency (AFSSA), which was merged into the French Agency for Food, Environmental and Occupational Health & Safety (ANSES) on 1 July 2010, received a solicited request on 22 February 2010 from the French Directorate General for Health (DGS) for an assessment of the health risks related to the installation, operation, maintenance and abandonment of renewable energy recovery systems in catchment protection zones (CPZs) used for the supplying of water intended for human consumption (WIHC) (See Annex 1).

1.2 Background and questions

With the French Planning Act No. 2005-781 (POPE Act) of 13 July 2005, which set out guidelines for energy policy, transposing Directive 2001/77/EC of 27 September 2001 into French law, France has committed to developing renewable energy, firstly to reduce its dependence on fossil fuels, pursuant to the Kyoto Protocol and secondly, to reduce its greenhouse gas emissions. It has set the following national objectives:

- to increase from 15% to 21% the share of national electricity consumption from renewable energy sources from wind, biomass, and to a lesser extent, hydroelectricity;
- to increase by 50% heat production from renewable (geothermal) sources by 2015.

It also adopted the objectives of the Grenelle Environment Round Table laws, which also advocate increasing the share of renewable energy in final energy consumption (to 23% by 2020).

Within this context, the pursuit of sectors supportive of the installation of renewable energy recovery systems (geothermal facilities, solar panels, wind turbines, etc.) is underway. The French Regional Health Agencies (ARSs) are thus increasingly being petitioned by developers and communities to install these systems in the catchment protection zones (CPZs) of water intended for human consumption and, in particular, in the inner protection zones (InPZs) because of the easements created here which, in some cases, may prohibit, suppress or limit the development of certain other activities, especially agricultural. Installation of these systems in the InPZs also releases communities from having to maintain them (mowing, for example).

In order to review these applications, the ARSs rely upon, where available, the provisions of prefectural orders issued under Article R. 1321-13 of the French Public Health Code (CSP), authorising collection of water intended for human consumption, including the declaration of public utility (DPU) of the CPZs and associated easements.

The CPZs aim to protect water resources from pollution (mainly occasional and accidental) that can render the water unfit for consumption. Three zones can be established:

- an immediate protection zone (ImPZ) around the catchment whose land must be acquired outright by the beneficiary of the DPU[1] and which should be enclosed, barring exceptions. The purpose of the ImPZ is to prevent the deterioration of withdrawal structures and prevent spills or seepage from pollutants and microbiological contaminants occurring in or in immediate proximity to the catchment;

[1] *When these lands are under the domain of the State, they should only be subject to a management agreement pursuant to the State-owned property code.*

- an inner protection zone (InPZ) that must be effective in protecting the catchment from subterranean migration of pollutants. Its extent varies depending on the hydrogeological context and thus may lead to prohibition or restriction of works, installations, activities, disposals, structures, development or use of lands, etc., that could cause pollution liable to make the water unfit for human consumption;
- an optional outer protection zone (OPZ), corresponding to all or part of the recharge area of a capture device not covered by the InPZ and in which there may be restrictions on works, installations, activities, disposals, structures, development or use of lands, etc., that may be the source of considerable pollution, and when the introduction of special requirements appears likely to significantly lower the risks for the water withdrawn.

Two situations then arise:

- either the application to install renewable energy recovery systems is included in the prefectural order of the DPU of the CPZs, and the response to the application must comply with its requirements (as seen in recent proceedings),
- or it is not included therein and requires the modification of this prefectural order at the request of the community (this was the case with earlier procedures that did not include the development of renewable energies). In this latter case, the installation of renewable energy recovery systems may encounter certain restrictions such as the inability to build on some plots or to build new roads.

However, there is currently no national health policy concerning the installation of renewable energy recovery systems in CPZs, which considers the possible risks of pollution of collected water resulting from these installations.

Wind, hydropower, solar, biomass and geothermal are the main renewable energy sources. These are used essentially to produce electricity or heat (heating and/or domestic hot water production).

Concerning hydropower, AFSSA’s 2008 report on the installation of hydroelectric plants on drinking water supply systems (whether or not located within CPZs) recommends identifying hazards and assessing the risk of water contamination in advance. AFSSA’s guidelines point to the risks this type of technology entails and the measures that should be taken to contain them (AFSSA 2008a).

The expert assessment conducted within the framework of this Request considered only the risks to water resources intended for the production of WIHC.

Only underground resources have been considered. Indeed, unlike the collection of groundwater for which the land included in the CPZs plays an important role in protecting water quality by retaining or degrading pollutants and requires *de facto* a great expanse, the protection of surface water intakes aims merely to secure the water supply by ensuring that surface flows can reach them quickly. Consequently, the CPZs for the water intakes are comprised of narrow strips of land extending longitudinally in banks that are limited with respect to the water courses or bodies that supply them. The small surface area of the CPZs for water intakes, their location on the valley floor or in basins, in a flood zone or a fluctuation zone adjacent to the water bodies, make these zones less suitable for the installation of renewable energy recovery systems.

Shallow geothermal energy (Canadian wells or Provençal wells) only involves superficial excavation of the ground (see § 2.1), aerothermal energy does not require excavation of the soil at all and stimulated deep geothermal energy (EGS – Enhanced Geothermal Systems), which is only at the experimental stage in France, has not been examined in the context of this Request. Similarly, biomass production facilities that have no specific impact on water resources have not been considered.

In addition, solar thermal and thermodynamic installations have not been addressed in this risk analysis because the individual thermal devices are primarily installed on buildings, and industrial thermodynamic devices that can be installed on the ground are not widely available[2] (See § 2.2.1).

Finally, any noise pollution, odours, aesthetic pollution (architectural or landscape impacts), air pollution (gas discharges for example) and/or impacts on fauna and flora, as well as risks for workers, have not been considered in this Request.

The objective of this work is:

- to analyse the main health risks associated with the installation, maintenance, operation and abandonment of various energy recovery systems (geothermal, solar, wind) in different catchment protection zones or, failing this and depending on the nature of the soil and hydrogeology, in the vicinity of the catchments when these zones have not been defined by regulation,
- to propose, as an example, measures for managing critical points identified that should be implemented and monitored when the installation of energy recovery systems is authorised.

1.3 Expert appraisal method

The expert appraisal was carried out in accordance with French Standard NF X 50-110 "Quality in Expert Appraisal Activities – General Requirements of Competence for Expert Appraisals (May 2003)".

The collective expert appraisal was entrusted to the Working Group (WG) on "Analysis of the health risks related to the installation, operation, maintenance and abandonment of renewable energy recovery systems (geothermal facilities, solar panels and wind turbines) in catchment protection zones for water intended for human consumption" formed on 5 May 2010.

The French Renewable Energies Professional Organisation (SER), the companies CFG Services and EOLE-RES, Électricité de France Énergies Nouvelles (EDF EN) and the French Bureau of Geological and Mining Research (BRGM) were all consulted by the WG.

The analysis of the health risks was carried out based on the following methods:

- Failure Mode, Effects and Criticality Analysis (FMECA),
- Hazard Analysis Critical Control Point (HACCP).

The risks to water resources were characterised by comparing the hazards associated with the impact of installations and/or operations during the various project phases (design, installation, use, maintenance and abandonment) and whether or not there are means to control them, with the vulnerability of the groundwater. This analysis considered data from the literature and the contents of the application dossiers for the installation of renewable energy recovery systems in CPZs intended for the production of WIHC received by the ARSs and forwarded to ANSES by the DGS

[2]None of the application dossiers for installation of devices using renewable energies in CPZs for the production of WIHC received by the ARSs and transmitted by the DGS concern this technology.

(31 applications including 14 related to wind, 11 to solar photovoltaic and six to geothermal energy).

The analysis conducted and the conclusions of the Working Group on “Analysis of the health risks related to the installation, operation, maintenance and abandonment of renewable energy recovery systems (geothermal facilities, solar panels and wind turbines) in catchment protection zones for water intended for human consumption” were adopted by ANSES’s CES on Water at its meeting of 5 July 2011.

2 List and description of renewable energy recovery systems

2.1 Geothermal energy

Geothermal energy is a technique that uses the heat energy from comparatively deep ground to produce heat and/or electricity. Heat capture takes place in contact with the ground (exchange between the solid matrix and air) and/or groundwater. The increase in temperature as a function of depth (geothermal gradient) is approximately 3 to 4°C/100 m in stable areas and can reach 10°C/100 m in active areas (active volcanic regions or tectonic zones).

Cold sources of geothermal energy are:
- geological layers: ground heat can be captured either by horizontal collectors (in the case of soil), or by vertical collectors,
- groundwater: used as cold sources for geothermal doublets.

The different types of geothermal energy, shown in the diagram (See Figure 1), are as follows (LeDu 2010):
- **high enthalpy (temperature >150°C)** and **medium enthalpy (temperature between 90°C and 150°C) geothermal energy** for heat and/or electricity production: the energy is extracted using a system of borehole doublets, one used to draw "hot" water or steam, the other to re-inject chilled water after heat exchange has taken place on the surface. To produce heat, water can be used directly, either in liquid form, or as steam. In this latter form, it can also drive a turbine to produce electricity (Baumgärtnet *et al.* 2005; Sustrac 2005a; Bouchot *et al.* 2010a; Gentier and Genter 2010). Stimulated deep geothermal energy (EGS), which is designed to extract the heat contained in deep rock (between 3 and 6 km deep) by hydraulic and/or chemical stimulation of the permeability of natural fractures in order to increase the flow and thus the electrical power produced, will not be considered in the risk analysis because it is only at the experimental stage in France (Soultz-sous-Forêts in Alsace);
- **low enthalpy geothermal energy (temperature between 30°C and 90°C)** for the production of heat: energy is harnessed using borehole doublets or a single structure system in which case the water is discharged into the near-surface environment or via a rain water network (Laplaige and Desplan 2005; Bouchot *et al.* 2010b);
- **very low enthalpy geothermal energy (temperature <30°C)** for the production of heat: the low temperature of the resource used (soil or water) does not allow the use of heat by direct exchange. The operation is performed using borehole doublets, a single borehole releasing into the surface environment, vertical or horizontal collectors, piles or more rarely, geothermal foundations requiring the use of a heat pump (Sustrac 2005b; Terrusse 2005);
- **surface geothermal energy (Canadian or Provençal wells)**: this exploits the soil temperature at shallow depths by circulating air between the outside and inside of a building in an underground pipe (1.5 to 3 m deep), through a ventilation system. The air entering the building is heated in winter and cooled in summer. This kind of device will not be considered in the risk analysis because it has no specific impact on groundwater resources (CETIAT 2008).

Facilities using low and very low enthalpy geothermal energy are the most common, the heat sources thus correspond to easily accessible shallow subsurface.

The various devices include:

- an energy capture system involving either water (open system) or a heat transfer fluid or refrigerant (closed system),
- an exchange system for releasing the calories (See § 2.1.1),
- where applicable, a system for discharging into groundwaters or surface waters when the calorie vector is water.

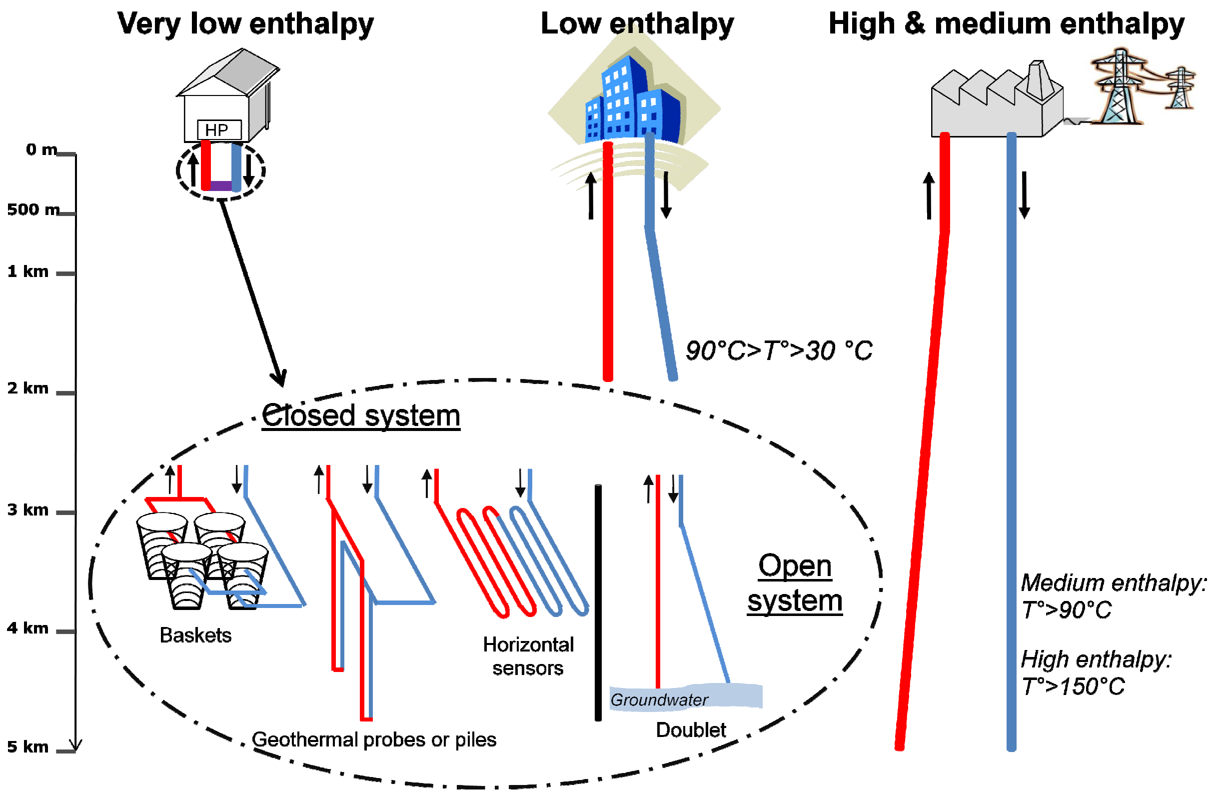


Figure 1: Schematic diagram of different types of geothermal energy considered in the risk analysis

2.1.1 Exchange systems

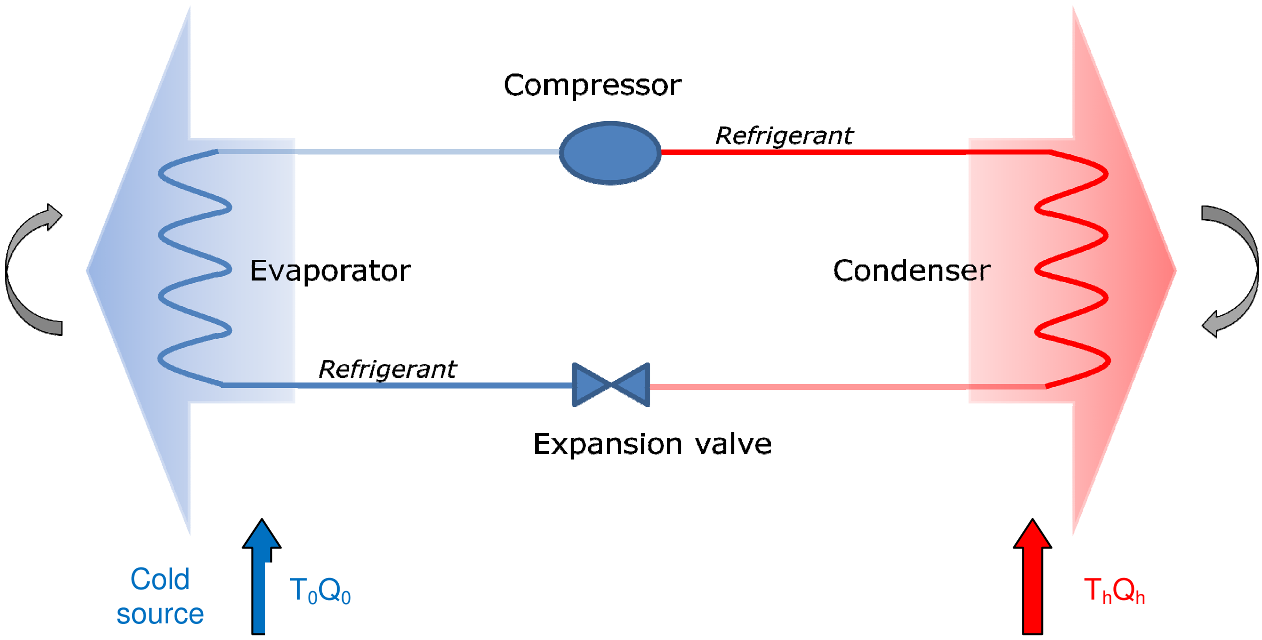
There are several types:

- various heat exchange or energy conversion systems (for example: plate, beam, turbine exchangers, etc.),
- heat pumps (HPs) needed for very low enthalpy devices which may be direct exchange, double exchange, single wall, double wall (Lemale and Gourmez 2008; Béranger 2008).

A HP is a thermodynamic system enabling either heating or cooling, depending on the direction of the refrigerant flow. There are also reversible HPs that can switch from heating to cooling mode depending on the season.

A HP consists of four main components: a compressor, condenser, expansion valve and evaporator. Heat taken from the environment is captured by the refrigerant (hydrofluorocarbon or hydrocarbon) in the evaporator where it changes its state and turns into vapour. The compressor pressurises this vapour, thereby increasing its temperature. It is in the condenser that the condensing vapour transfers its heat to the medium to be heated. The temperature of the refrigerant drops sharply, it becomes liquid and can again absorb heat in the evaporator, and the cycle can begin again (Lemane and Gourmez 2008; Riederer 2010).

To ensure the reliability and safety of the refrigerant circuit further elements are added, such as a supply of refrigerant, a dehydrator, a pressure surge control, and high and low pressure regulators.



Q_0: quantity of heat taken from the cold source.
Q_h: quantity of heat released at the heat source.
T_o: evaporation temperature at the cold source (evaporator).
T_h: condensation temperature at the heat source (condenser).

Figure 2: Diagram of a heat pump

2.1.2 The various systems for harnessing energy

2.1.2.1 Closed systems

2.1.2.1.1 Horizontal and basket geothermal systems

There are three types of horizontal systems:

- **the direct expansion process (soil/soil HP)** with refrigerant containing only a single circuit, without an exchanger. The refrigerant passes directly through an underground system of pipes and heat emitters. The horizontal systems consist of copper tubing coated with polyethylene and mostly now, high-density polyethylene tubes (e.g.: PE 100, XLPE) arranged horizontally (usually at a depth of about one metre) to capture heat from the soil. These underground pipes, curved into loops, with a total length of more than several hundred metres and 40 cm apart, transfer the captured heat via the refrigerant to the heat pump's evaporator (See Figure 3);

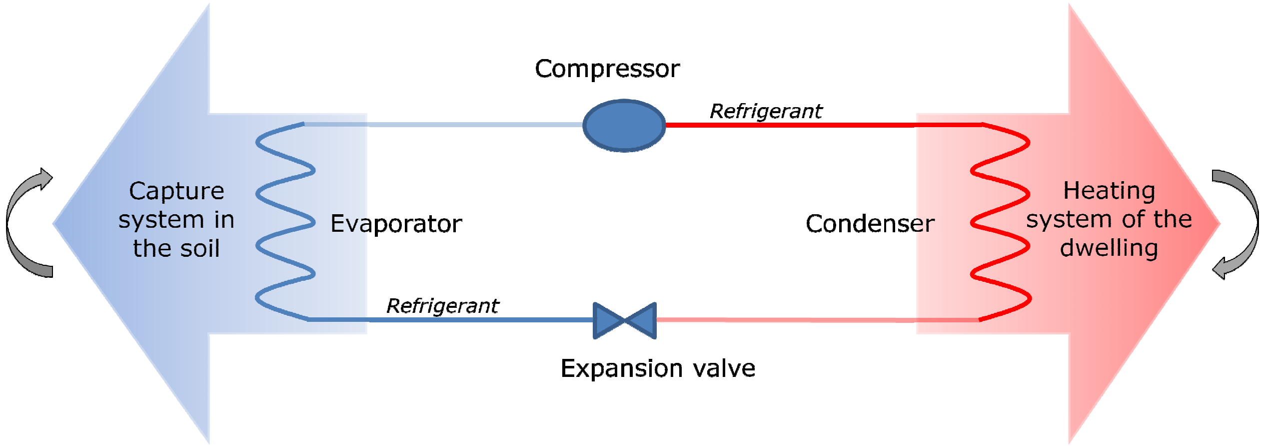


Figure 3: Diagram of a direct expansion process

- **the intermediary fluid process (glycol water/water HP).** This double exchange system consists of an underground network of horizontally arranged high-density polyethylene (HDPE) pipes in which the heat transfer fluid circulates. The refrigerant remains confined within the heat pump (See Figure 4);

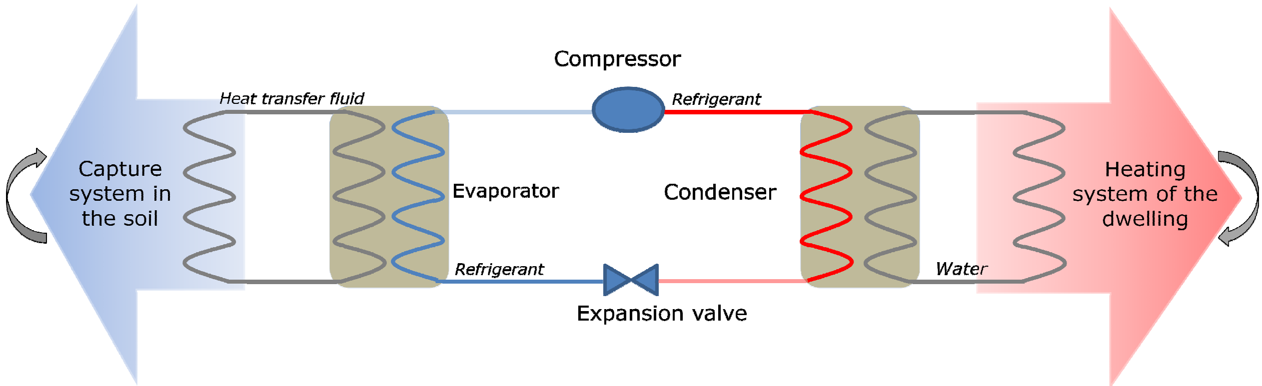


Figure 4: Diagram of an intermediary fluid process

- **the mixed process (soil/water HP)** in which the refrigerant circulates through underground HDPE pipes and the water in the heat emitters (See Figure 5).

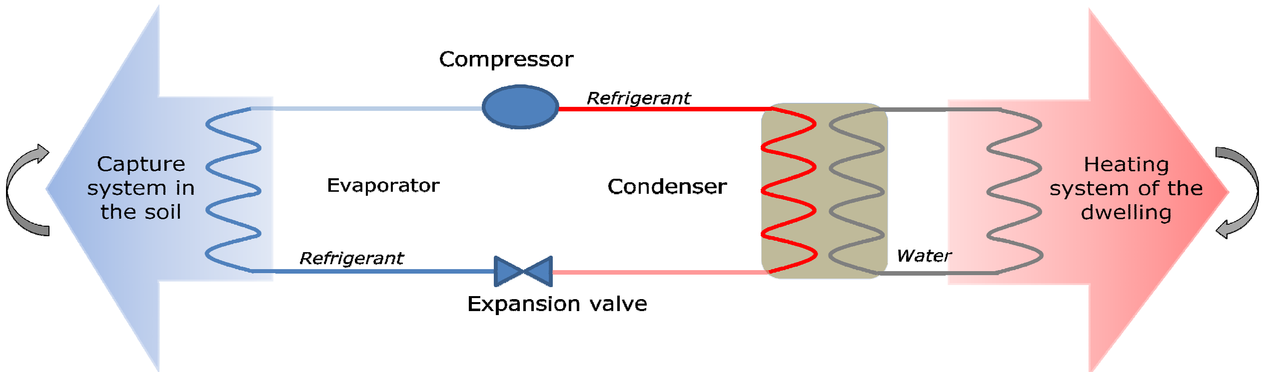


Figure 5: Diagram of a mixed process

Basket devices make it possible, in a restricted volume (height of two to three metres and diameter of 0.5 to 1.5 m) to install a length of 50 to 100 m of polyethylene exchange tubing. They require deeper excavations, the top of the baskets are placed about 1.5 m deep, the baskets about four metres apart and they are then interconnected to an intermediary fluid HP.

The horizontal and basket devices must be placed close to the building to be heated and require gently sloping land. The horizontal devices exploit a surface area that is one to two times that of the building, while the basket devices offer a gain of about 40% in surface area.

2.1.2.1.2 Vertical collectors and geothermal piles

Vertical collectors (geothermal probes, French Standard NF EN 10-970) operate by exchanging heat from the subsoil at depths of between several tens of metres and 400 m. Depending on the hydrogeological context, the base of the collector can be located either in the unsaturated zone of the aquifer, or in the groundwater. The most commonly used probes are composed of U-tubes made of synthetic material (for example: PE 100, XLPE) placed in a bored area and in which a heat transfer fluid circulates, in a closed circuit, driven by a circulation pump (Albouy *et al.* 2005).

The intermediary fluid process is the only one used for this application.

The seal between the collector and the layer is ensured by injecting a bentonite/cement slurry into the borehole, guaranteeing the optimum thermal conductivity, imperviousness and resistance to physico-chemical stresses. The French Standard NF X 10-970 (January 2011) recommends filling up to one metre below the ground surface to help make the trench that serves as a link between the exchangers and the equipment room, while French Standard NF X 10-999 (April 2007) recommends filling up to the surface.

The captured heat is released in a heat pump evaporator.

The number of collectors and thus the number of boreholes to be drilled is based on the volume to be heated, and the facilities/structures must be placed more than ten metres apart.

In addition, the vertical collectors can be installed at the core of the building foundations (geothermal piles or foundations). Reinforced concrete piles usually have a diameter of 0.4 to 1.5 m and a depth ranging from a few metres to over 30 m. Inside these piles one or more U-tubes (double or quadruple U) made of synthetic material (for example: PE 100, XLPE) are installed, which are then embedded in concrete to ensure good thermal contact. The number of piles depends on the volume to be heated. The intermediary fluid process is the only one used for this application and the heat transfer fluid is typically water.

2.1.2.2 Open systems

Depending on the depth to be reached, the boreholes are made employing the techniques used when prospecting for water or oil. They are generally fitted with black steel tubes cemented to the outer surface in the non-producing depths of boreholes and passing through the groundwater to be protected.

The water collected in the groundwater generally passes through a heat pump exchanger. However, it is possible to use the water for cooling or heating without using a HP.

In heating mode, these devices produce cold discharges (collection of calories) and for cooling, warm discharges (release of calories):

- when the water is reinjected into the groundwater, the drilling of two boreholes is necessary (geothermal doublets). The second borehole must be drilled downgradient and laterally in general in order to avoid thermal interference between the collected water and the reinjected water,
- when the water is released into the near-surface environment, if necessary via the rainwater system, a single borehole is drilled.

The lifespan of closed polyethylene horizontal and vertical systems is at least 100 years (manufacturer’s data). The lifespan of the polyethylene-coated copper collectors is probably shorter.

Amortisation of the cost of a borehole is calculated over 20 years. The lifespan of the boreholes with the geothermal doublets will vary not only according to the characteristics of the water collected (corrosive or scaling action and sometimes both, but at different points of the structure) but also as a function of pile phenomena and the flow of telluric currents in the ground (electrochemical corrosion).

2.1.3 Products used in geothermal energy

2.1.3.1 Products used during drilling or borehole development

Air, foam (surfactants and polyacrylamide-based additives) or admixed muds (soda, mineral oils, polymers, polysaccharides, deflocculants, acidification residues, etc.) may be used during drilling (Coz 2009).

French Standard NF X 10-999 (April 2007) specifies that the fluids used (water, air, mud, etc.) must meet the requirements for safety and protection of the environment and also comply with current standards, and that the use of muds with polymers must not induce microbiological risks.

Furthermore, the lubricants used on the driller and for greasing the threads of the rods carrying the drilling tool are made, for the most part, of the following materials (ANSES 2010):

- 60 to 90% of a lubricating base which can be petroleum-based, synthetic or natural (plant or animal),
- 10 to 20% thickeners: fatty acid metal salts (soaps), bentonite, polytetrafluoroethylene (PTFE), silica, graphite, etc.,
- 5% additives that each account for between 0.1 and 0.5%: corrosion inhibiters, antioxidants, adhesion promoters, defoamers, etc.

Borehole development may require the use of acid (hydrochloric acid, etc.) in the case of deposits or incrustation containing iron salts, or polyphosphates (hexametaphosphate, etc.) in the case of clay deposits (Coz, 2009).

2.1.3.2 Hydraulic binders (concrete, mortar and grout)

Hydraulic binders used for cementing consist of (DGS 2008a; CIMbéton 2005):

- cements (common cements, aluminous cements, quick-setting natural cements, etc.),

- aggregates (from natural sources, meaning that they have undergone no treatment other than mechanical, or artificial from heat-treated rocks, minerals, waste, demolition materials, etc.),
- mixing water (WIHC, groundwater or surface water, seawater, or brackish water);

to which mineral or organic substances may be added:

- mineral additives (limestone fillers, fly ash, ground granulated blast furnace slag, silica fumes, etc.);
- additives and admixtures:
    - cohesion agents,
    - organic product emulsions added to the mixing water (butadiene-styrene, acrylic or epoxy resins, etc.),
    - plasticisers/water-reducers (sodium or calcium lignosulphates, polynaphthalene sulphonates, polycarboxylates, gluconates, triethanolamine, polymelamine sulphonates, isothiazolones, etc.),
    - water retentive agents (celluloses, etc.),
    - air entrainers,
    - setting accelerators (calcium chloride, etc.) or hardening agents,
    - setting retarders (glucoses, sucroses, etc.),
    - integral waterproofer (stearic acid, etc.),
    - other;
- fibres (metallic, such as cast iron or steel fibres, minerals such as glass or carbon fibres, organic fibres, such as polyolefin, polypropylene, polyacrylonitrile, polyvinyl alcohol, polyamide and linear polyester, etc.).

Grouts, mortars and concretes are made from the same basic ingredients and are differentiated by the nature and size of the aggregates used: absent or very fine for grout, fine (sand) for mortar and coarse (sand, gravel) for concrete.

For boreholes and vertical collectors, the grout filler is a cement-based fluid mixture of additives, water, possibly fine loads smaller than 0.3 mm (suspensions of clay or bentonite) and admixtures (CIMbéton 2006).

French Standard NF X10-999 (April 2007) specifies that the slag should be composed of water and thoroughly mixed cement, the use of quick-setting cement is not recommended, cement-bentonite mixtures can be used provided that the proportion of bentonite does not exceed 5% of the cement weight and that it be hydrated 24 hours before cementing.

The draft French Standard prNF X 10-950 establishes requirements for the cement used in geothermal energy.

In addition, the documentation booklet FD P 18-011 (December 2009) provides guidelines, especially for selecting cements for the manufacture of concrete for structures subjected to harsh chemical environments.

2.1.3.3 Curing compounds and demoulding agents

To make geothermal piles, demoulding agents (vegetable oils, etc.) may be applied to the formwork materials, and curing compounds (resin or wax-based dissolved in a petroleum solvent) may be applied to the surface of hardened concrete to prevent cracking or crazing during drying.

2.1.3.4 Products used in collectors and heat pumps

Various fluids can be used in HPs for the transfer of calories/negative kilocalories; refrigerants are in a gaseous state at ambient temperature and pressure, whereas heat transfer fluids are always in a liquid state.

Since exchange circuits are sealed, except in the event of an accident (leaks), they should not come into contact with the water resource used for the production of WIHC.

Moreover, in open vertical systems, other products may be used.

2.1.3.4.1 Refrigerants

Refrigerants belong to several classes of compounds that are used pure or mixed (Béranger 2008):

- hydrofluorocarbons (HFCs):
  - R-134a[3] which replaces R-12[4], a chlorofluorocarbon (CFC) that is now banned,
  - R-407c[5] which replaces R-22[6] (hydrochlorofluorocarbon – HCFC, which will be banned by 2012 because of its impact on the ozone layer),
  - R-410a[7], a refrigerant which undergoes phase change at an almost constant temperature and which is widely used in air conditioning systems,
  - R-404a[8] most often used in ground source heat pumps,
  - R-417a[9] seldom used currently;
- hydrocarbons such as R-290 (propane) and R-600a (isobutane), but which can only be used in small quantities and outside homes, because of their flammability;
- ammonia (R-717), which presents a toxic fume hazard in case of leakage.

The use of these greenhouse gases is strictly regulated and increasingly limited (See Annex 5).

2.1.3.4.2 Heat transfer fluids

These fluids mostly consist of water and ethylene- or propylene glycol-based antifreeze. Depending on the material composition of the collectors, they may contain in particular the following additives (DGS/PGE/1.D. Circular No. 942 of 2 July 1985; DGS/PGE/1.D. Circular No. 357 of 2 March 1987):

- anti-corrosion agents (alkanolamines, alkaline carbonates, benzoates, silicates, alkaline phosphates, alkaline sulphites, polyamines, imidazoles, etc.);
- biocides, algaecides and fungicides (1,2-benzisothiazol-3(2H)-one, 2-methyl-2H-isothiazole-3-one, quaternary ammonium compounds, etc.);
- dispersing and sequestering agents (benzalkonium chlorides, polyacrylic acids and sodium polyacrylates, tetrasodium ethylenediaminetetraacetate, etc.);
- wetting agents, detergents (lecithins, polyethylene glycols, amino alcohol fatty esters, quaternary ammonium compounds, etc.);

[3] *R-134: 1,1,1,2-tetrafluoroethane ($C_2H_2F_4$).*

[4] *R-12: Dichlorodifluoromethane (CCl_2F_2).*

[5] *R-407c: Zeotropic blend of 52% R-134a, 25% R-125 (pentafluoroethane) and 23% R-32 (difluoromethane).*

[6] *R-22: Chlorodifluoromethane ($CHClF_2$).*

[7] *R-410a: Blend of 50% de R-32 (difluoromethane) and 50% R-125 (pentafluoroethane).*

[8] *R-404a: Zeotropic blend of 52% R-143a (1,1,1-trifluoroethane), 44% R-125 4% R-134a.*

[9] *R-417: Blend of 46.6% R-125, 50% R-134a and 3.4% butane.*

- anti-foaming, anti-redeposition agents or thickeners (methylpolysiloxanes, xanthum gum, etc.);
- dyes;
- other.

French Standard NF X 10-970 (January 2011) establishes requirements for heat transfer fluids used in vertical geothermal probes (See Annex 5).

Moreover, the use of heat transfer fluids in direct exchange or single-wall heating circuits for the production of domestic hot water is regulated to protect consumers of WIHC in the event of damaged heat exchangers (AFSSA 2008b). Although this regulation does not apply to heat transfer fluids used in underground geothermal heat pump exchangers, it prevents the sale of the most toxic heat transfer fluids for consumers (See Annex 5).

Ethylene- or propylene glycol-based heat transfer fluids will degrade in the aerated part of the ground (unsaturated zone). Also, propylene glycol degrades in about ten days while ethylene glycol has an estimated half-life of between two and 12 days. However, during a significant spill, ethylene glycol lightly adsorbed on soil particles can quickly migrate to the groundwater (Gonsior and West 1995; Canada 2000).

2.1.3.4.3 Other products

Corrosion inhibitors, sequestering and dispersing agents intended to limit clogging, etc., may be injected into the boreholes (See § 2.1.3.2).

Table I: Summary of systems using geothermal energy

Type of geothermal energy	**High enthalpy**	**Medium enthalpy**	**Low enthalpy**	**Very low enthalpy**			
Temperature of the resource	>150°C	Between 90°C and 150°C	Between 30°C and 90°C	<30°C			
Approximate depth	4 to 6 km	2 to 4 km	1 to 2 km	0.5 to 1.5 m	3 to 10 m	50 to 400 m (10 to 30 m for the piles)	400 to 800 m
Use	Electricity	Electricity Heat	Heat	Heat	Heat	Heat	Heat
Energy capture system	Open system Doublet of boreholes	Open system Doublet of boreholes	Open system Doublet of boreholes or Single borehole with discharge into the near-surface environment	Closed system Horizontal collector (Horizontal loop)	Closed system Basket	Closed system Vertical collector (probe and piles) (Vertical loop)	Open system Doublet of boreholes or Single borehole with discharge into the near-surface environment
Type of HP				Direct expansion, Mixed , Intermediary fluid,	Intermediary fluid	Intermediary fluid	In the building
Products used in the collectors	Water may also contain corrosion inhibitors and/or sequestering and dispersing agents			Refrigerants and/or heat transfer fluids			Water

2.2 Solar thermal and photovoltaic energy

Solar energy can be used to:
- recover heat: solar thermal energy,
- produce electricity: solar photovoltaic energy.

2.2.1 Solar thermal and thermodynamic energy

A traditional solar thermal installation generally includes five systems respectively for: heat capture, transfer, storage, auxiliary electrical power and distribution. The collectors convert solar radiation into heat and pass it to the heat transfer fluid circulating in the tubes of the collectors and in the primary circuit. A heat exchanger (a tank in the case of hot water production) transmits the heat to the secondary circuit. Finally, an auxiliary electrical system may be used to reach the recommended water storage temperature to prevent the development of *Legionella* [Ministerial Order of 30 November 2005] (See Figure 6).

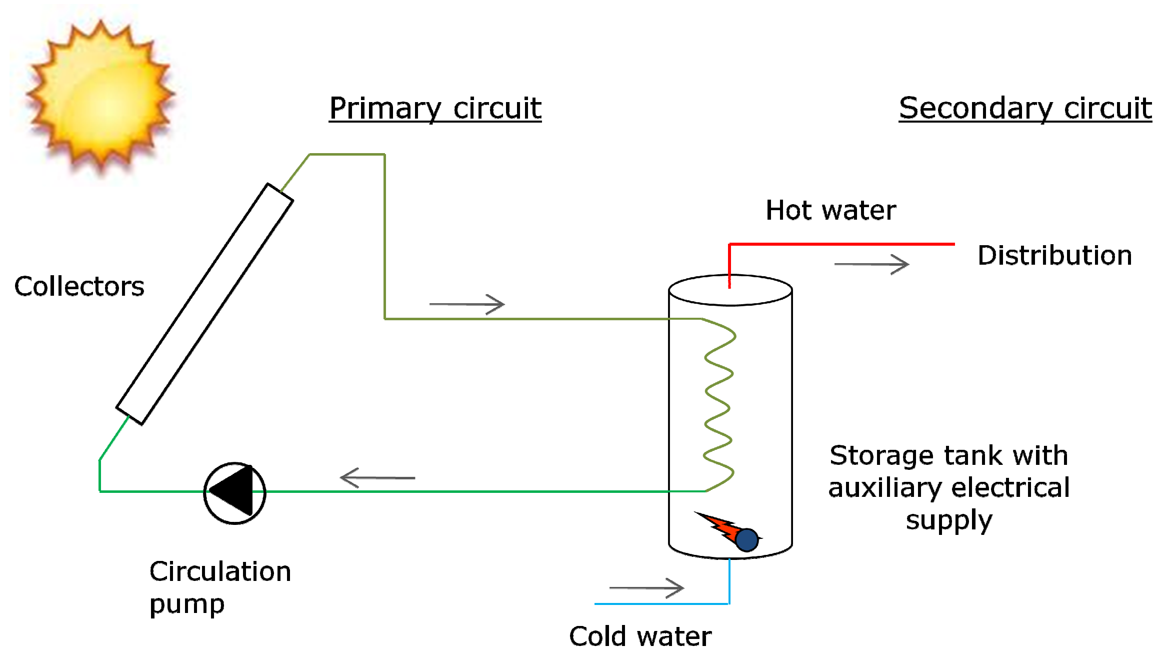


Figure 6: Simplified diagram of a solar thermal installation

Solar thermal energy can be used to produce hot water (for heating, swimming pools, and domestic hot water) in individual dwellings or multiple-occupancy buildings.

Solar thermodynamic energy can be used for industrial production of heat or electricity through a heat exchanger. Sunlight is concentrated using parabolic collectors or a "solar power tower"[10]. The installation potential of these stations remains limited in mainland France, because of the levels of sunlight and clear skies required.

A risk analysis with respect to water resources connected to individual thermal devices primarily installed on buildings, and to industrial thermodynamic devices not in widespread use, has not been addressed in this report.

2.2.2 Solar photovoltaic energy

A photovoltaic power plant produces electricity from light energy from the sun[11]. This energy transformation takes place through photovoltaic cells consisting of one or two thin layers of semi-conductive material (INGEROP).

The solar collectors (modules or panels) consist of photovoltaic cell arrays located on mounting brackets to ensure the mechanical strength and tightness of the system.

Photovoltaic cells may be of various types, mainly:

- crystalline silicium, composed of thin slices cut from a single crystal [monocrystalline cells (Mono c-Si)] or a block of silicium crystals [polycrystalline cells (Poly c-Si)];

[10] *http://sfp.in2p3.fr/Debat/debat_energie/websfp/rivoire.htm*

[11] *http://www.ademe.fr/midi-pyrenees/a_2_08.html*

- thin sheets made of very fine layers of photosensitive material deposited on a base such as glass, stainless steel or plastic. The photosensitive material deposited on the base may be:
    - cadmium telluride cells (CdTe),
    - copper indium selenium cells (CIS).

Silicium cells are most commonly used for roof installations and cadmium telluride cells (CdTe) are used for ground installations. Cadmium telluride photovoltaic panels contain approximately seven grams of cadmium, mainly in the form of cadmium telluride (CdTe) and small amounts of cadmium sulphide (CdS) (Lincot *et al. 2009*):

- cadmium atoms (Cd) form strong bonds with telluride (Te) and sulfur (S) atoms. Thus, if a panel breaks, even if leaching of Cd were possible, it will be limited and very slow;
- layers containing cadmium are placed between two glass plates, each 3 mm thick. Thus, in case of fire, leaks are limited by the glass plates, and by melting glass fusing into an inert matrix.

An energy storage system (usually batteries) is added to the device for sites unconnected to the power grid. This type of installation is used mainly in remote areas to supply standalone electrical equipment (street lamps, parking meters, lighthouses, etc.), when connecting to the public grid would be too expensive or when there is no grid in the vicinity.

In the case of devices connected to the power grid, the direct current from photovoltaic modules must be converted to standard alternating current (230-240 Volts – 50 Hertz) using an inverter. If necessary, a transformer can be installed to raise the output voltage to the level for input into the grid (See Figure 7).

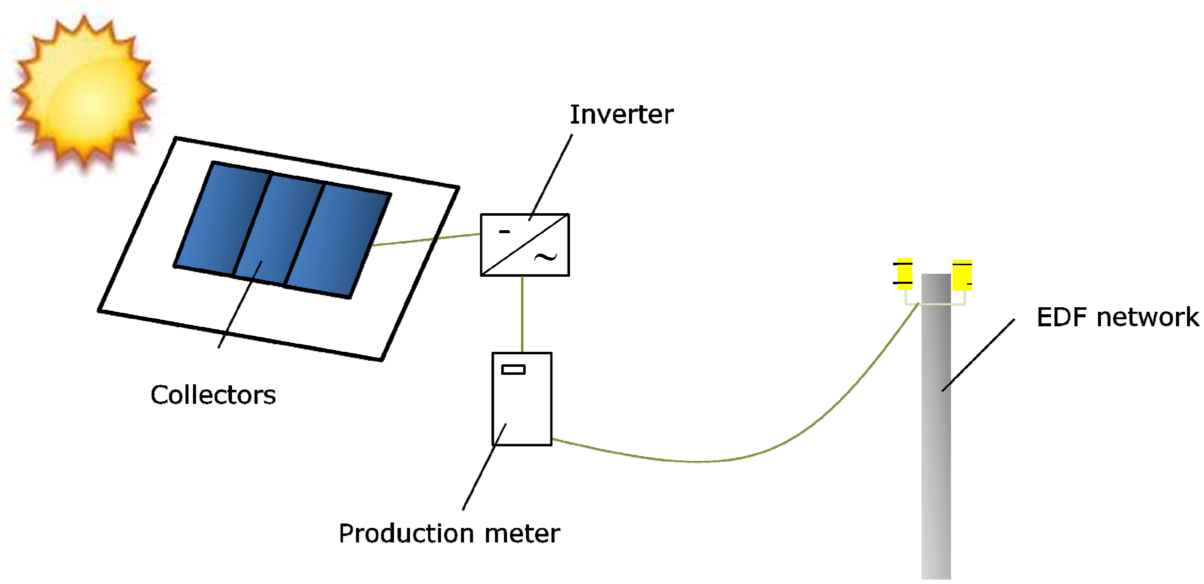


Figure 7: Diagram of a photovoltaic installation

Solar collectors can be installed on roofs or on the ground. Roof installations will not be considered in the risk analysis because they have no particular impact on underground water resources.

Stationary solar collectors (in rare cases, they move to follow the sun's path) are mounted on a base of zinc-plated steel, aluminium or sometimes wood.

The ground installations are arranged in rows and are usually anchored using concrete blocks that are 50 cm in diameter (anchored at a maximum depth of 120 cm) or tapped and threaded screws 150 mm in diameter (anchored at a maximum depth of 2 m). Floating foundations for heavy loads with concrete cross-members prepared onsite or prefabricated are less commonly used (subsoil resistant to pile driving or fill which prevents driving piles). In the latter case, the anchoring depth is limited to 60 cm deep (Nessi *et al.* 2011).

The above-ground height of the solar panels ranges from two to over three metres.

The frames of the collectors are generally connected to the inverters using underground cables, placed side by side on a 10 cm layer of sand at the bottom of a trench about 80 cm deep (Nessi *et al.* 2011). The spacing between the cables and the width of the trench depends on the amperage of the planned current. Cables that can be buried directly are replacing cables that must be encased. The burial depth of the cables can be decreased or increased (1.20-1.30 m) particularly on agricultural land.

The total area of a photovoltaic system corresponds to the industrial site, generally enclosed, and including access roads for maintenance vehicles, parking spaces, manoeuvring areas, maintenance facilities and technical facilities. The latter include the photovoltaic panels area, which coversthe largest area, the shelters housing the inverters, transformers (which can contain more than 500 kg of oil), the production meters and various electrical protection systems, the delivery station that accommodates incoming cables and provides the connection with the public power grid, and other open areas (Nessi *et al.* 2011; MEDDTL 2011). The prefabricated shelters are generally placed in a pit 60 cm deep on a 10 cm bed of sand.

The surface area of the installation depends on:

- the nature of the mounting on the base (mobile or stationary installation) and the height of the modules that determine, among other things, the space required between the rows,
- yields,
- site features (slope of the ground, geographic location). With installations in lowlands, a minimum distance between the rows of panels is necessary to reduce any shadows cast.

At a given site, the power of a photovoltaic power station is proportional to the area of the installed modules. For example, the area of facilities in France ranges from 2 to 3 ha/MWp[12] (MEDDTL 2011).

The lifespan of a photovoltaic installation is estimated to be twenty years.

The dismantling of these facilities, not currently mandatory, may be total. Solar panels are not generally cleaned, except by rain. The grounds are maintained regularly to avoid shade on the structures and fire risks. As modules produce direct current, firefighters allow installations to burn during a fire.

[12]*ha/MWc: hectare per megawatt peak.*

2.3 Wind energy

Wind turbines or wind generators convert the force of the wind into electricity. A wind turbine consists of blades, usually three, carried by a rotor and installed at the top of a vertical mast. This assembly is mounted on a nacelle that holds a generator and an electric motor that directs it toward the wind (See Figure 8).

Wind, whose velocity must be between 14 and 90 km/h (over this speed wind turbines are stopped for safety reasons), drives the blades at a rate of 10 to 25 revolutions per minute and the mechanical energy created by the rotation is transformed by the generator into energy that can supply the power grid.

There are different types of wind turbines:

- large wind turbines with a power of 2 MW that can supply electricity, not including heating, to approximately 2000 homes. Their masts are approximately 100 m high and the blades are 50 m long;
- small wind turbines with an output of 0.1 to 20 KW that either supply buildings that are off the power grid, or are themselves connected to the grid. Mast height ranges from 10 to 35 m.

The construction of a wind turbine requires foundations that are smaller in surface area with respect to the elevation of the machine:

- excavations from 3 to 5 m in depth with a diameter of 15 to 20 m,
- a concrete base of about 400 m^3 is poured into the excavations. If the load-bearing capacity of the ground is inadequate, anchor piles or compacted columns (concrete columns with a metal frame), as applicable, are built. As a result, the anchors can penetrate a few tens of metres deep. The types of concrete, curing and demoulding agents that may be used are specified in § 2.1.3.2 and 2.1.3.3.

Currently, geotechnical studies to define foundation depths are not generally conducted before obtaining the building permit.

The wind turbine is connected to the power grid using underground cables buried at a depth of about 0.80 m, but that can be extended to 1.20-1.30 m below agriculture land. Cables that can be buried directly are replacing cables that must be encased.

Building a wind turbine requires moving massive heavy pieces and creating access roads or upgrading existing ones, as well as a crane-manoeuvring surface area of about 1000 m^2. The construction time for a wind farm is several months (six to 10).

Four hundred to over 700 litres of lubricant can be used in a wind turbine (See § 2.1.3.1), with the nacelle serving as a retention tank. The transformers are dry or equipped with a holding tank. The nacelle and blades are fitted with lightning conductors.

The lifespan of a wind turbine is approximately twenty years[13].

[13] *All manufacturers offer 25-year production warranties (power generation is still 90% of the initial production rate after 10 years and 80% after 25 years). Existing installations show that the modules can continue producing for 30 years (MEDDTL 2011).*

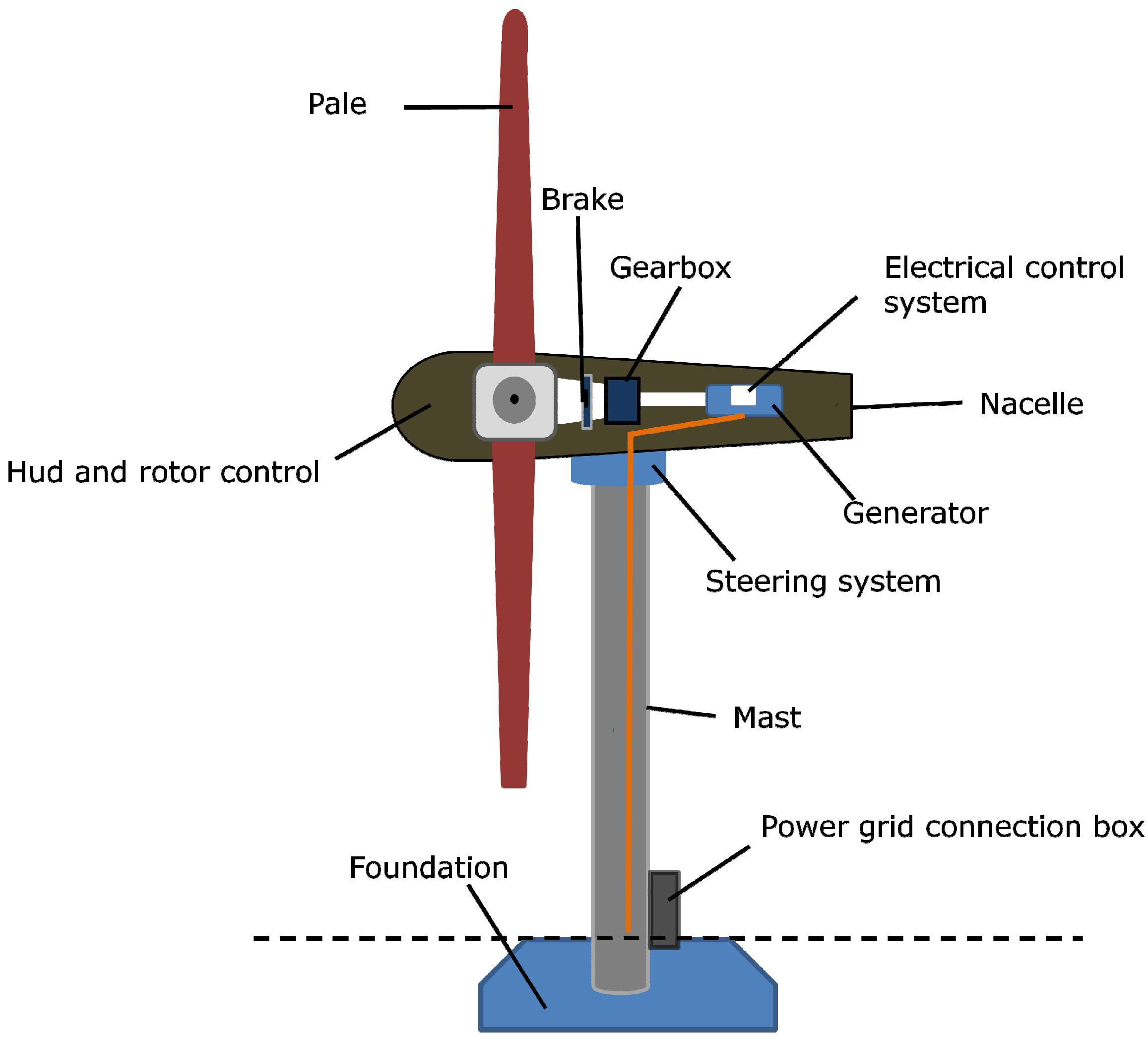


Figure 8: Diagram of a wind turbine

3 Analysis of the health risks inherent in renewable energy recovery systems and possible control measures at critical points

The analysis of the health risks related to the installation, maintenance, operation and abandonment of renewable energy recovery systems in catchment protection zones for water intended for human consumption was carried out based on the following methods:

- Failure Mode, Effects and Criticality Analysis (FMECA),
- Hazard Analysis Critical Control Point (HACCP).

Risks to water resources were characterised by comparing:
1) the hazards associated with the impact of the installations and/or implementations during different phases of the projects and whether or not there are means to control them:

- design phase,
- installation phase,
- operation and maintenance phase,
- abandonment phase;

2) with the intrinsic vulnerability of the groundwater being exploited.

This analysis considered data from the literature and the contents of the application dossiers for the installation of renewable energy systems in catchment protection zones for the production of water intended for human consumption received by the ARSs and forwarded to ANSES by the DGS.

3.1 Impact of the installations

N.B.: only operations likely to have an impact on underground water resources were taken into account.

Table II: Impact of geothermal energy facilities – Horizontal and basket closed systems

	implementation		Hazard	Means of control
Installation phase	Site operations	Movement of construction equipment and transport vehicles	Compaction of the soil, partial surface sealing *However, limited areas involved*	None
		Maintenance of vehicles and equipment Use of power generators	Seepage of pollutants (especially hydrocarbons) *However, short-term construction site (1 week)*	Maintaining and repairing equipment outside the CPZs Having anti-pollution kits (absorbing agents and flocculants) on site
	Excavation of the ground (**Horizontal systems)**	Excavation of a pit 1 to 2 m deep and several hundred m^2, and a trench about 30 m long	Area made more permeable which promotes seepage *However, small expansion area and shallow depth*	Backfilling at the end of construction, but area generally remains more permeable
	Excavation of the ground (**Basket systems)**	Digging of several holes 3.5 m deep and a trench 60 cm wide and less than 1 m deep	Areas made more permeable which promotes seepage *However, small surface areas and shallow depth*	Backfilling at the end of the construction, but area generally remains more permeable
	Filling collectors with refrigerants or heat transfer fluids		Leakage of heat transfer fluids or refrigerants - Contamination of groundwater *However, the refrigerant fluids are volatile and the heat transfer fluids are discharged in the unsaturated zone where degradation of the glycol portion is possible*	Checks of the assembly, water pressure testing (Riederer 2010) Use of a water/propylene glycol non-admixed blend or heat transfer fluids included on list "A[14]
Operation and maintenance phase	Supply of heat transfer fluids		Leakage of heat transfer fluids - Contamination of groundwater *However, the refrigerant fluids are volatile and the heat transfer fluids are released in the unsaturated zone where degradation of the glycol portion is possible*	Use of a water/propylene glycol non-admixed blend or heat transfer fluids included on list "A"
	Deterioration of the underground networks		Leakage of heat transfer fluids or refrigerants - Contamination of groundwater *However, the refrigerant fluids are volatile and the heat transfer fluids are released in the unsaturated zone where degradation of the glycol portion is possible*	Identifying and marking underground networks
Abandonment phase	System draining		Leakage of heat transfer fluids - Contamination of groundwater *However, the refrigerant fluids are volatile and the heat transfer fluids are released in the unsaturated zone where degradation of the glycol portion is possible*	Recovery of the fluid for destruction or recycling by approved bodies (Riederer 2010) Use of a water/propylene glycol non-admixed blend or heat transfer fluids included on list "A"
	Abandonment of the network			Keeping track of the location of the abandoned installation

[14] *Circular DGS/PGE/1.D. No. 942 of 2 July 1985 on heat treatment of water intended for human consumption.*

Table III: Impact of geothermal energy facilities – Vertical closed systems

	Implementation		Hazard	Means of control
Installation phase	Site development	Creation of access roads (some paved), storage areas	Soil compaction, partial surface sealing Potentially contaminated water runoff *However, limited areas involved*	Limiting deployed areas Creating tracks, if possible, outside the CPZs Protecting the site against runoff (diverting water)
		Storage of hazardous products (hydrocarbons, for example)	Seepage of pollutants *However, short-term construction site (1 to 2 weeks)*	Storage in retaining basins
	Site operations	Movement of construction site vehicles including the driller and transporter	Soil compaction, partial surface sealing *However, limited areas involved*	None
		Maintenance of vehicles and equipment Use of power generators	Seepage of pollutants (especially hydrocarbons) *However, short-term construction site (1 to 2 weeks)*	No storage of hydrocarbons and fluids in the CPZs Maintaining and repairing equipment outside the CPZs Having anti-pollution kits (absorbing agents and flocculants) on site
	Drilling of boreholes (vertical collectors)	Drilling	Reaching the groundwater	None
			Connecting independent groundwater reservoirs	There is no means of control for the technology involved in this process
		Possible mud: - creation of a mud trap - injection of drilling mud	Seepage and pollution of the groundwater by mud additives (sodium hydroxide, mineral oils, polymers, polysaccharides, deflocculants, acidifying residues, etc.) or microorganisms found in water used to prepare mud	Complying with best practices in engineering (French Standard NF X 10-970) Use a "QualiForage" approved driller
			Fouling of the aquifer horizons crossed	
			In karst areas, increasing turbidity of underground water as a result of mud leakage and potential seepage of pollutants	
		Use of lubricants on the drill and the threads of the drill rods	Pollution of the groundwater (hydrocarbons)	
		Use of admixed grout	Alkalinisation, migration of aluminium, metals or organic substances in the groundwater *However, limited areas involved*	
	Construction of foundations (geothermal piling)	Use of concrete admixtures, curing compounds and form-stripping oil	Concrete grout in karst cavities	Even though techniques exist to prevent the flow of concrete into the cavities (concealing excavations), they do not eliminate the hazard
			Preferential seepage along the walls	Using polymer sheeting on the bottom and around the periphery of the pit Making a watertight casing to prevent seepage of concrete slurry
			Alkalinisation, migration of aluminium, metals or organic substances in the groundwater	Complying with best practices concerning choice and use of concrete
	Filling the collectors and piles with heat transfer fluid		Leakage of heat transfer fluids - Contamination of groundwater *Low volume of spilled heat transfer fluid. But degradation of the glycol portion may not be possible due to insufficient thickness of the unsaturated ground*	Checks of the probe assembly, water pressure testing (Riederer 2010) Using a water/propylene glycol non-admixed blend or heat transfer fluids included on list "A"

	Implementation	Hazard	Means of control
Operation and maintenance phase	Supply of heat transfer fluids	Leakage of heat transfer fluids - Contamination of groundwater *Low volume of spilled heat transfer fluid. But degradation of the glycol portion may not be possible due to insufficient thickness of the unsaturated ground*	Using a water/propylene glycol non-admixed blend or heat transfer fluids included on list “A”
	Aging of the seal between the probe or the piles and the ground	Seepage of stray water along the probes or piles Contamination of groundwater	None
	Maintenance performed by workers not belonging to the water production and/or distribution service	Workers unfamiliar with the risks related to WIHC	Establishing agreements among various stakeholders, specifically stipulating their respective responsibilities Training workers
Abandonment phase	Draining of the CPZs	Leakage of heat transfer fluids - Contamination of groundwater *Low volume of spilled heat transfer fluid. But degradation of the glycol portion may not be possible due to insufficient thickness of the unsaturated ground*	Recovering the fluid for destruction or recycling by accredited approved (Riederer 2010) Using a water/propylene glycol non-admixed blend or heat transfer fluids included on list “A”
	Abandonment of probes and piles	Seepage of stray water along the probes or piles Contamination of groundwater	Plugging and sealing the probe according to best practices Keeping track of the location of the abandoned probe

Table IV: Impact of geothermal energy facilities – Open systems

	Implementation		Hazard	Means of control
Design phase	Seismic exploration using explosives		Local modification of the seepage *However, the use of seismic explosives is rare*	None
	Mechanical exploration	Drilling	Reaching the groundwater	None
			Connecting independent groundwater reservoirs	Complying with best practices (French Standard NF X 10-970) Using a "QualiForage" approved driller
		Drilling muds using the rotary technique: - creation of a mud trap - injection of mud during drilling	Seepage and pollution of the groundwater by mud additives (sodium hydroxide, mineral oils, polymers, polysaccharides, deflocculants, acidifying residues, etc.) or microorganisms found in water used to prepare mud	
	Abandonment of the borehole		Connecting independent groundwater reservoirs	Complying with the best practices (French Standard NF X 10-970) Use a "QualiForage" approved driller
			Contamination of groundwater by infiltration of stray water	Removing the casing and filling the structures according to best practices
Installation phase	Site development	Creation of access roads (some paved), maintenance and parking areas, buildings	Soil compaction, partial surface sealing Potentially contaminated water runoff *However, limited areas involved*	Limiting deployed areas Creating tracks, if possible, outside the CPZs Protecting the site against runoff (diverting water)
		Storage of hazardous products (hydrocarbons, for example)	Seepage of pollutants	Storage in retaining basin
		Clean-up of site buildings	Seepage of pollutants	Establishing site clean-up in accordance with regulations
	Site operations	Movement of heavy site vehicles and transporters	Soil compaction, partial surface sealing *However, limited areas involved*	None
		Supply and maintenance of vehicles Use of power generators	Seepage of pollutants (especially hydrocarbons)	No storage of hydrocarbons and fluids in the CPZs Maintaining and repairing equipment outside the CPZs Having anti-pollution kits (absorbing agents and flocculants) on site
	Drilling	Drilling	Access to groundwater	None
			Connecting aquifer reservoirs	Complying with the rules of practice (French Standard NF X 10-970) Using a "QualiForage" approved driller None
		Drilling muds using the rotary technique: - creation of a mud trap - injection of mud during drilling	Seepage and pollution of the groundwater by mud additives (sodium hydroxide, mineral oils, polymers, polysaccharides, deflocculants, acidifying residues, etc.) or microorganisms found in water used to prepare mud	
			Fouling of the aquifer horizons crossed	
			In karst areas, increasing turbidity of groundwater as a result of mud leakage and potential seepage of pollutants	
		Use of lubricants on the drill and the threads of the drill rods	Pollution of the groundwater (hydrocarbons)	
		Development of the borehole	Seepage and pollution of the groundwater by the products used (acids, polyphosphates)	
		Use of admixed grout	Alkalinisation, migration of aluminium, metals or organic substances in the groundwater *However, limited areas involved*	

	Implementation	Hazard	Means of control
Operation and maintenance phase	Water abstraction	Direct and permanent access to the groundwater	None
		Interference with other work exploiting the same groundwater source	Plans developed by the authorities for using geothermal energy Piezometric monitoring of the groundwater crossed
		Draws water of lower quality (e.g.: salt water)	Conducting a preliminary feasibility study of the impact of pumping
		Connecting groundwater sources following breach of the casing due to corrosion	Using corrosion inhibitors
	Reinjection of used water into the groundwater	Direct and permanent access to the groundwater *Except in cases of discharge into the near-surface environment*	None
		Long-term changes in the temperature of an area of the groundwater (plume), increasing or decreasing depending on use (heating or cooling)	Alternating uses
		Alteration of the physico-chemical characteristics of the groundwater (solubility of gases dissolved in the water, pH and balance of dissolved compounds) Warming of the water is accompanied by: - reduction in dissolved gas levels (loss of CO_2) - change in the mineralisation of the water due to the increased solubility of many organic and mineral substances and heavy metals Conversely, a cold discharge may promote precipitation processes (risk of clogging by precipitation of carbonates, iron hydroxide, manganese hydroxide, etc.*)* These changes in the groundwater chemistry around the injection structure may promote corrosion phenomena (water mineralisation, presence of stray electrical currents and/or certain bacterial strains) and are accompanied by contamination of underlying groundwater (Jaudin 1988; Bonte *et al.* 2011b)	None
		Possible use of corrosion inhibitors, sequestering and dispersing agents if twater is corrosive or scale-forming	None
		Alteration of microbiological characteristics of the groundwater due to the increased water temperature (a determining factor for the ecology of bacteria) or the introduction of nutrients. Although research has not revealed the development of pathogenic species (Winters 1992) or increased cell count, it has shown a change in microbial flora (Sowers *et al.* 2006; Brielmann *et al.* 2009; Bonte *et al.* 2011a; Bonte *et al.* 2011b)	None
		Connecting groundwater sources following breach of the casing due to corrosion	Use of corrosion inhibitors
	Rehabilitation of the boreholes	Seepage and pollution of one or more groundwater sources by cleaning and disinfection products (acids, polyphosphates, disinfectants)	Removal by pumping
	Maintenance performed by workers not belonging to the water production and/or distribution service	Workers unfamiliar with the risks related to WIHC	Establishing agreements among various stakeholders, specifically stipulating their respective responsibilities Training workers
Abandonment phase	Abandonment of the borehole	Connecting groundwaters	Removing the casing and filling the structures according to best practices
		Groundwater contamination by seepage of stray water	

Table V: Impact of solar photovoltaic energy installations

Phase	Implementation		Hazard	Means of control
Installation phase	Site development	Creation of access roads, a storage platform and haul roads	Soil compaction, partial surface sealing *However, limited areas involved*	Limiting surfaces deployed Creation of access roads and of a storage platform outside of the CPZs, if possible, or use of existing roads
		Storage of hazardous products (hydrocarbons, for example)	Seepage of pollutants	Storage in retention basins
		Site clean-up	Seepage of pollutants	Establishing site clean-up in accordance with regulations
	Site supervision	Movement of site and transport vehicles	Seepage of hydrocarbons *However, use of haul roads*	None
		Vehicle maintenance, use of power generators	Seepage of pollutants (especially hydrocarbons).	No storage of hydrocarbons and fluids in the CPZs Maintaining and repairing equipment outside the CPZs Having anti-pollution kits (absorbing agents and flocculants) on the site
	Changes to the site topography		Displacement and mixing of earth Altering soil permeability and flow conditions, possibility of hydrocarbon seepage	Ban on reworking the site
	Installation or building of solar panel supports		Possible soil stripping, creation of drainage areas Soil sealing *However, in a small area*	Choice of ground supports
			Surface sealing of the soil *However, in a small area*	Choice of low impact foundations (e.g.: piles)
	Installation of prefabricated shelters or construction of buildings for electrical and maintenance equipment		Surface sealing of the soil *However, in a small area*	Installing, if possible, outside the CPZs
	Laying of underground cables and junction boxes		Displacement and mixing of earth Altering soil permeability Preferential seepage of the trenches (=drains)	Laying 'direct burial' cables
Operation and maintenance phase	Use of vehicles		Seepage of pollutants (hydrocarbons) *However, traffic and frequency on haul roads limited*	None
	Use of various materials for mounting the modules		Leaching of metallic elements (e.g.: Zn^{2+} with galvanised steel) *However, possible retention in the unsaturated zone of the ground*	None
	Covering of the soil by the modules (30 to 35% total impact for an installation arranged in rows).		Concentration of precipitation at the base of the modules	None, with respect to change of flow
			Changes in seepage and runoff	Adequate panel spacing to ensure hydraulic transparency
			Soil erosion	Maintaining vegetation cover to limit erosion
	Use of electrical equipment (inverters, transformers, supply terminal, cables, modules, etc.)		Fire Combustion by-products poorly understood (mobility and toxicity) No possibility of extinguishing the combustion *However, concerning cadmium-tellurium panels (Cd-Te), cadmium leaks are limited by the glass plates and by formation of an inert matrix with the glass during fusion (Lincot et al.)*	Complying with electrical equipment standards Using fire-resistant shelters Installing lightning conductors that comply with standards Maintaining ground vegetation within and surrounding the facility Creating a strip with no vegetation on the periphery of the facility Connecting an automatic alarm system to an emergency response service
	Maintenance performed by workers not belonging to the water production and/or distribution service		Workers unfamiliar with the risks related to WIHC	Establishing agreements among various stakeholders, specifically stipulating their respective responsibilities Training workers
	Cleaning of surfaces of the modules		Discharge of cleaning products *However, generally self-cleaning by rain water*	Using exclusively water
	Maintenance of vegetation on the property		Leaching of herbicides	Mechanical maintenance
	Panel breakage		Possible leaching of Cd *However, limited and very slow (Lincot et al.) and retained in the unsaturated zone of the ground*	None

	Implemantation	Hazard	Means of control
Abandonment phase	Abandonment of concrete parts or panels	Partial surface sealing	Recovering and recycling of used panels Thorough site cleaning, ploughing and restoration of the grassland
	Abandonment of the cables	Preferential seepage zones	None
	Opening trenches to remove cables	Displacement and mixing of earth Altering soil permeability Preferential seepages of the trenches (=drains)	Building embankments

Table VI: Impact of installations using wind energy

	Implementation		Hazard	Means of control
Installation phase	Site development	Creation of access roads (some paved), and crane manoeuvring areas	Soil compaction, partial surface sealing *However, limited areas involved*	Limiting surfaces deployed Creating access roads outside the CPZs, if possible, or use existing roads
		Storage of hazardous products (hydrocarbons, for example)	Seepage of pollutants	Storage in retention basins
		Site clean-up	Seepage of pollutants	Establishing site clean-up in accordance with regulations
	Site operations	Movement of heavy site vehicles and transporters	Soil compaction, partial surface sealing *However, limited areas involved*	None
		Vehicle fuelling and maintenance Use of power generators	Seepage, especially of hydrocarbons	No storage of hydrocarbons and fluids in the CPZs Maintaining and repairing equipment outside the CPZs Having anti-pollution kits (absorbing agents and flocculants) on site
	Excavation of pits up to 5 m deep with a diameter of 20 m. Sometimes necessary to have stone columns or piles that can reach twenty metres in depth		Impacts the groundwater or reduction of the protective layer above the water table *Note: geotechnical studies to define the depth of the foundations are not generally conducted before obtaining the building permit when this should be compulsory*	None
	Pits open for several weeks		Creation of a preferred path for seepage	Pouring the concrete immediately after completion of the pits
	Possible use of 'rock breakers'		Creation of cracks and seepage	None
	Use of admixed concrete (400 m^3 per wind turbine), curing compounds and form-stripping oils		Flow of concrete into the karst cavities	Even though techniques exist to prevent the flow of concrete into the cavities (concealing excavations), they do not eliminate the hazard
			Preferential seepage along the walls	Using polymer sheeting on the bottom and around the periphery of the pit Making a watertight casing to prevent seepage of concrete
			Alkalinisation, migration of aluminium, metals, or organic substances into the groundwater	Complying with best practices concerning the choice of concrete and its use
	Cleaning the cement mixers containing the concrete		Seepage of pollutants	Cleaning outside of the CPZs
	Installation or construction of ancillary buildings for electrical equipment		Partial surface sealing *However, limited areas involved*	Installing outside of the InPZ, when possible
	Laying underground cable		Altering soil permeability Preferential seepage of the trenches (=drains)	Laying 'direct burial' cables
	Supply of oil for the gearbox (up to 700 L)		Oil spill *However, the nacelle serves as the retention tank*	None

	Implementation	Hazard	Means of control
Operation and maintenance phase	Use of vehicles	Seepage of hydrocarbons *However, limited areas and frequencies involved*	None
	Lubrication of moving parts (once yearly, for example)	Oil spill *However, the nacelle serves as retention tank*	None
	Use of dielectric fluids in the transformers and/or condensers	Leakage of dielectric fluids	Using dry transformers and/or condensers or installing them on a retention tank
	High installation (over 100 m)	Lightning during thunderstorms, fire	Protecting installations against lightning Connecting an automatic alarm system to an emergency response service
	Maintenance performed by workers not belonging to the water production and/or distribution service	Workers unfamiliar with the risks associated with WIHC	Establishing agreements among various stakeholders, specifically stipulating their respective responsibilities Training workers
Abandonment phase	Abandonment of concrete foundations and some equipment	Partial surface sealing and preferred seepage	Salvaging all equipment above ground Demolishing the surface portion of concrete blocks Thorough site cleaning
	Abandonment of cables	Preferred seepage areas	None

3.2 Vulnerability of the groundwater in catchment protection zones

Vulnerability of the groundwater depends on:

- the type of groundwater (confined, semi-confined or unconfined),
- and for unconfined groundwater:
  - the thickness of the unsaturated zone and thus the depth of the groundwater,
  - the permeability of the unsaturated zone.

3.2.1 Confined and semi-confined groundwater

Their impermeable or semi-impermeable cap provides protection against seepage of most contaminants from the moment this cap establishes continuity. This protection is particularly effective firstly, if this cap is thick and secondly, if the groundwater has a high hydraulic load. However, in the case of semi-confined groundwater, independent phenomena of drainage natural or induced by the use of catchments, which can promote the seepage of certain compounds, should not be overlooked. Confined and semi-confined groundwater has little or no vulnerability if the clay cap that protects the groundwater is totally or partially preserved.

3.2.2 Unconfined groundwater

The thickness as well as the permeability of the ground comprising the unsaturated zone will determine this zone's ability to retain and help degrade certain contaminants.

Unconfined groundwater sources whose piezometric surface is not very deep (less than ten metres in high water) are vulnerable (and even more so if the ground is highly permeable) whereas those with a permeable saturated zone whose piezometric surface is more than ten metres deep, are not.

When the unsaturated zone is not argillaceous and/or fractured, permeability is high ($K > 10^{-4}$ m/s) and groundwater protection is low. Conversely when the ground is argillaceous or compact (K from 10^{-4} to 10^{-7} m/s) groundwater protection is high.

Table VII: Vulnerability of unconfined groundwater

	Groundwater piezometric surface <10 m	**Groundwater piezometric surface >10 m**
Permeability $>10^{-4}$ m/s	Groundwater vulnerable	Groundwater less vulnerable
10^{-7} m/s < Permeability $<10^{-4}$ m/s	Groundwater somewhat vulnerable	Groundwater not vulnerable

Given the heterogeneity in karst environments, installation projects for renewable energy recovery systems should include a vulnerability study of the sector concerned, paying specific attention to:
- the existence or absence of a protective cap,
- the density of seepage zones, the amount of runoff water, etc.

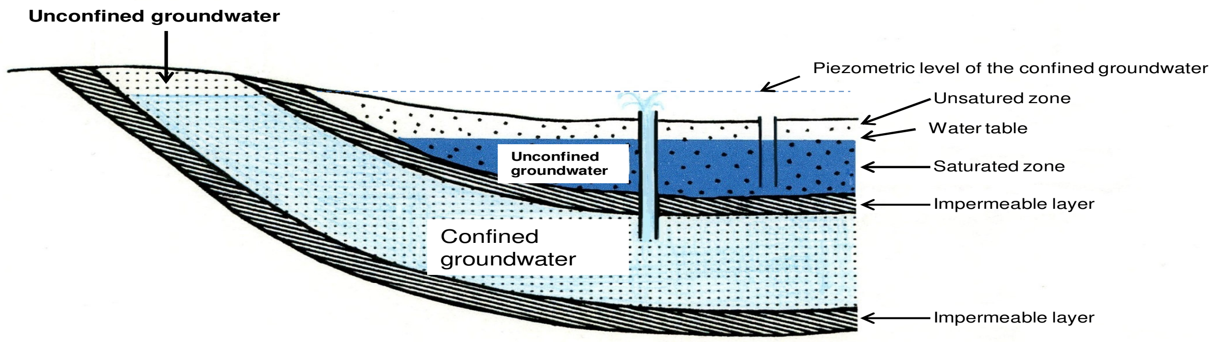


Figure 9: Diagram representing types of groundwater sources and their vulnerability

3.3 Results of the risk analysis

The risks of degradation of the groundwater quality, related to the installation of renewable energy systems in CPZs, are ascertained from a comparison of the inherent hazards in various phases of the project (design, installation, use, maintenance, abandonment) and whether there are means for controlling them, with the intrinsic vulnerability of the groundwater being exploited. The phase of the project that poses the greatest risks to the groundwater determines the overall risk associated with the installation of a system.

In ImPZs, because the installations being built are very close to the water collection structures and because people unqualified in matters of WIHC have access to this zone, the risk is high. Moreover, in light of regulatory provisions relating to CPZs, the initiation of new activities outside of those explicitly authorised in the DPU is prohibited and, because of the risk mentioned, the installation of renewable energy systems in the ImPZ of a catchment should not be among the authorised activities.

The risk related to installing renewable energy systems in InPZs is outlined in detail in Table VIII. Furthermore, in karst areas, the risks related to the installation of renewable energy systems can only be assessed on a case-by-case basis after a vulnerability study conducted by a hydrogeologist licensed in public health (Ministerial Order of 15 March 2011).

In OPZs, if management measures are implemented for all the hazards identified, the risks will be lower than in the InPZs due to the distance of the system from the water intake point. In addition, with regard to regulatory provisions relating to CPZs, the installation of renewable energy systems in the OPZs cannot be prohibited but only regulated.

When the catchment does not have a CPZ, the risk related to the use of renewable energy systems in the recharge area of the capture device can only be assessed on a case-by-case basis with respect to their proximity to the water intake. This assessment must be made by a hydrogeologist licensed in public health (Ministerial Order of 15 March 2011).

In addition, any plans to install renewable energy recovery systems must be consistent with public utility easements (established by prefectural or ministerial orders), local land-use planning documents and current regulations.

Table VIII: Results of the risk analysis related to the installation of renewable energy systems in inner protection zones (InPZs)

Vulnerability of the groundwater * / Type of installation	Confined and semi-confined groundwater (no unsaturated zone)	Unconfined groundwater with a piezometric surface <10 m deep in high water		Unconfined groundwater with a piezometric surface >10 m deep in high water	
		Permeable unsaturated zone ($>10^{-4}$ m/s)	Semi-permeable unsaturated zone (from 10^{-7} to 10^{-4} m/s)	Permeable unsaturated zone ($>10^{-4}$ m/s)	Semi-permeable unsaturated zone (from 10^{-7} to 10^{-4} m/s)
Geothermal energy recovery system Closed loop (Baskets and horizontal sensors)	**Insignificant risk**	**Moderate risk**	**Low risk**	**Low risk**	**Low risk**
Geothermal energy recovery system Vertical closed loop (probes and piles)	**Insignificant risk** (if the cemented base of the probes or piles is more than 3 m above the base of the impermeable groundwater cap) **Moderate to high risk** (if the cemented base of the probes or piles is less than 3 m above the base of the impermeable groundwater cap)	**High risk**	**High risk**	**High risk**	**High risk**
Geothermal energy recovery system Vertical open loop	**High risk**	**High risk**	**High risk**	**High risk**	**High risk**
Solar photovoltaic energy installation	**Insignificant risk**	**High risk**	**Low risk**	**Low risk**	**Low risk**
Wind energy installation	**Insignificant risk** (if the base of the foundations is more than 3 m above the base of the impermeable groundwater cap) **Moderate to high risk** (if the base of the foundations is less than 3 m above the base of the impermeable groundwater cap)	**High risk**	**High risk**	**Low risk** (if the base of the foundations is more than 3 m above the highest groundwater levels) **High risk** (if the base of the foundations is less than 3 m above the highest groundwater levels)	**Insignificant risk** (if the base of the foundations is more than 3 m above the highest groundwater levels) **Moderate to high risk** (if the base of the foundations is less than 3 m above the highest groundwater levels)

Karst environment: *case-by-case vulnerability study (See subsection 3.2).*

4 Regulatory background

4.1 French Public Health Code (CSP): Provisions on catchment protection zones for water intended for human consumption

Under Articles L. 1321-2 and R. 1321-13 of the CSP, the determination of protection zones is mandatory around the public intake points for water intended for human consumption (DGS 2009). The CPZs include:

- An immediate protection zones (ImPZ): “*Within the immediate protection boundary, whose limits are established in order to prohibit any direct introduction of pollutants into the water and prevent the degradation of structures, closed-off land, unless there is a derogation laid down in the public utility declaration, and are regularly maintained. Other works, installations, activities, disposals, structures, facilities or land uses are prohibited, except those explicitly authorised in the public utility declaration.*”
- An inner protection zone (InPZ), in which “*works, installations, activities, disposals, structures, facilities or land uses that may lead to pollution that renders the water unfit for human consumption are prohibited. Other works, […] may be subject to requirements, and are subject to specific monitoring.*”;
- An optional outer protection zone (OPZ), in which, *“works, installations […] that, considering the nature of the land, pose a risk of pollution to abstracted or transported water, owing to the nature and quality of pollutants associated with these activities […] or the extent of the surfaces that they occupy, may be regulated*”.

The establishment of CPZs is a regulatory mechanism that helps protect the intake points from occasional and accidental pollution that may occur in their near environment. The French Ministry of Health’s technical manual published in May 2008 specifies the objectives to be achieved by these protection boundaries (DGS 2008a):

- The ImPZ, of limited extension (a few hundred m^2 in general), is intended to protect the catchment from wilful damage, direct spillage on the structure and microbial contamination (parasites, bacteria, viruses);
- The InPZ should be a buffer zone for any at-risk activities taking place near the catchment protection boundary. This zone should offer sufficient reaction time with respect to any pollution that might occur. Activities underway during its development do not preclude the production of good quality water, although some improvements of the situation may be necessary. However, and except for confined groundwater catchments, the possibility of prohibiting all new activity should be considered (graded according to the type of aquifer);
- The OPZ is generally inapplicable, except from the perspective of managing the diffuse pollution of an aquifer.

Only the ImPZ is mandatory, but for the vast majority of resources (resources without natural protection), the InPZ is essential.

The CPZs and related easements are established in declarations of public utility by prefectural order authorising use of the catchment to produce water for human consumption (adopted under Article R.1321-6 of the CSP), which is entered:

- in the planning documents of the town(s) concerned (POS, PLU), to be taken into account for development projects on municipal lands;
- in the collection of administrative acts.

It may also be entered in the mortgage registry, although this is no longer required since Act 2004-806 of 9 August 2004.

The ARSs rely on the provisions of prefectural orders on the DPU of the CPZs, as applicable, to review applications for the installation of renewable energy recovery systems therein. If provisions for installation of these systems do not appear in the prefectural orders on the DPU of the CPZs, the opinion of a hydrogeologist licensed in public health, formally requested by the ARS, must be obtained (Ministerial Order of 15 March 2011) and, if necessary, the prefectural order must be amended.

4.2 Regulatory and other provisions applicable to installations using renewable energy

The installation of renewable energy systems is primarily regulated by the following codes and their by-laws:

- the Mining Code,
- the Environmental Code,
- the Local Authorities Code,
- the Urban Code,
- the Public Health Code if their installation is planned in CPZs (See § 4.1.1).

The objective of these different codes is to manage soil and subsoil use, to monitor water withdrawal and discharges with respect to the protection of water resources, but also to protect the public from noise pollution, preserve aesthetics, prevent air pollution, and protect fauna and flora, etc.

Regulations, technical standards, guidelines and certifications applicable to different types of installations and products used in them, are specified in the following annexes:

- Annex 2: Geothermal facilities,
- Annex 3: Solar photovoltaic panels,
- Annex 4: Wind turbines,
- Annex 5: Products used in renewable energy systems.

5 Conclusions

The risks of degradation of the quality of groundwater, related to the installation of renewable energy recovery systems in CPZs, are ascertained from a comparison of the inherent hazards in various phases of the project (design, installation, use, maintenance, abandonment) and whether there are means for managing them, with the intrinsic vulnerability of the groundwater being exploited. The phase of the project that poses the greatest risks to the groundwater determines the overall risk associated with the installation of a system.

The risk described below relates to the overall risk of degradation of groundwater quality.

1) In the ImPZ, the risk related to the installation of renewable energy systems is considered to be high due to the close proximity of the installations to be built with the catchment structures for WIHC and access to this zone by people unqualified in matters of WIHC. In addition, with regard to regulatory provisions related to CPZs, the initiation of new activities outside of those explicitly authorised in the DPU is prohibited and, because of the risk mentioned, the installation of renewable energy systems in the ImPZ of a catchment should not be among the authorised activities.

2) In the InPZ, the risk related to the installation of renewable energy systems is provided in detail in Table IV.

The risk related to the installation of horizontal closed loop and basket geothermal systems is considered to be insignificant, low or moderate, depending on the vulnerability of the groundwater, because these systems are shallow and will not be located in the groundwater to be collected.

The risk related to the installation of vertical closed loop geothermal systems is considered to be high with unconfined groundwater because there is no guarantee of a complete seal between the probes or the piles and the soil, nor that the systems will age well and that stray water will not seep along the probes or the piles. However, the risk is considered to be insignificant with confined or semi-confined groundwater, provided that a clay-like cap is maintained between the cemented base of the probe or the piles and the underlying groundwater in order to keep the latter under pressure (cemented base of the probes or piles more than 3 m above the base of the impermeable groundwater cap).

Concerning geothermal doublets (open-loop), the risk related to their installation in InPZs is considered to be high, irrespective of groundwater vulnerability.

The risk related to solar photovoltaic installations is considered to be low or insignificant, except in permeable environments, in zones where the groundwater is unconfined and shallow (<10 m).

For wind turbine installations, the risk is considered to be:

- insignificant for confined or semi-confined groundwater if the base of their foundations allows for a thickness of at least 3 m from the screen it is resting on;
- high for shallow unconfined groundwater (piezometric surface <10 m);
- low or insignificant for unconfined groundwater with a piezometric surface in high water that lies at a depth of > 10 m, provided that the base of the foundation lies at more than 3 m above the high water mark of the groundwater.

Furthermore, in karst areas, the risks related to the installation of renewable energy systems can only be assessed on a case-by-case basis following a vulnerability study conducted by a hydrogeologist licensed in public health.

Any accident in a system using renewable energy installed in an InPZ that may have an impact on the quality of the water must be reported immediately to the ARSs. A technical review of the operation of renewable energy systems installed in the InPZ describing the incidents and their possible impact on the quality of the water must be provided to the ARSs annually.

3) In the OPZ, and if management measures are implemented for all the hazards identified, the risks will be lower than in the InPZ due to the distance of the system from the water intake point. In addition, with regard to regulatory provisions relating to CPZs, the installation of renewable energy systems in the OPZ cannot be prohibited but only regulated.

Moreover, it should be emphasised that the pollution risks for aquifers will be the same, whether or not they are used for the production of WIHC, hence the need for systems that may be installed outside CPZs to observe the same requirements as for those located within their boundaries, in order to safeguard future resources.

4). When the catchment does not have a defined CPZ, the risk related to the use of renewable energy systems in the recharge area of the capture device can only be assessed on a case-by-case basis with respect to their proximity to the water intake. This assessment must be made by a hydrogeologist licensed in public health.

6 Selected references, regulations and standards

6.1 References

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Act No. 2004-806 of 9 August 2004 on the public health policy.
Act No. 2010-874 of 27 July 2010 on the modernisation of agriculture and fishing.

Decree No. 78-498 amended 28 March 1978 on titles for prospecting and exploitation of geothermal energy.
Decree No. 2000-877 of 7 September 2000 on authorisation to operate electrical power plants.
Decree No.2001-410 of 10 May 2001 on the purchase conditions of electricity generated by producers benefitting from the obligation to purchase.
Decree No. 2006-648 of 2 June 2006 on mining titles and underground storage rights.
Decree No. 2006-649 of 2 June 2006 on mining operations, underground storage works and policing of mines and underground storage.
Decree No. 2007-1307 of 4 September 2007 on the application of Act. No. 2000-108 of 10 February 2000 as amended, on the modernisation and development of the electric utility and related transitional provisions.
Decree No. 2008-652 of 2 July 2008 on the reporting of abstraction devices, wells or boreholes for domestic water use and their monitoring along with private installations for distribution of drinking water.
Decree No. 2009-496 of 30 April 2009 on the administrative authority of the state competent in environmental matters under Articles L. 122-1 and L. 122-7 of the Environmental Code.
Decree No. 2009-1414 of 19 November 2009 on administrative procedures for certain electrical power plants.
Decree No. 2010-1700 of 30 December 2010 amending column A of the annex to Article R. 511-9 of the Environmental Code on the nomenclature of classified installations for the protection of the environment.

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Ministerial Order of 5 December 2006 on methods for measuring ambient noise.
Ministerial Order of 17 December 2008 on monitoring of private installations for distribution of drinking water, abstraction devices, wells and boreholes and rainwater recovery systems.
Ministerial Order of 15 March 2011 on procedures for accreditation, designation and consultation of hydrogeologists for public health.

Circular of 26 April 1982 on the amendment of the Standard Departmental Health Regulation (Annex concerning heat treatment of water intended for human consumption).
Circular DGS/PGE/1.D. No. 942 of 2 July 1985 on heat treatment of water intended for human consumption - Article 16-9 of the Standard Departmental Health Regulation.
Circular DGS/PGE/1.D. No. 357 of 2 March 1987 on the updated list of fluids and additives used for heat treatment of water intended for human consumption.
Circular of 3 March 2008 on disruption by wind turbines of the operation of fixed radars from civil aviation, national defence, Météo-France, and ports, marine and river navigation (PNM).
Circular of 3 September 2009 on the preparation of the opinion of the environmental authority.
Circular of 18 December 2009 on development and monitoring of ground-mounted photovoltaic power plants.

6.3 Standards

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Annex 1: Letter of request

2010-SA-0047

French Ministry of Health, Youth and Sports

Paris, 22 February 2010

Directorate General for Health
Sub-directorate for Environmental and Food Risk Prevention
Bureau of Water Quality

DGS/EA4 No. 64

Person responsible for the file:
Ms Bérengère LEDUNOIS
Tel: 01.40.56.69.18
Fax: 01.40.56.50.56
E-mail: berengere.ledunois@sante.gouv.fr

request [*illegible*]
(for discussion)
[initials]

The Director General for Health

to

The Director General of the
French Food Safety Agency
Department for the Evaluation of
Nutritional and Health Risks (DERNS)
27-31 rue du Général Leclerc
BP 19
94701 MAISONS-ALFORT CEDEX

A.F.S.S.A. Reçu le 26 FEV. 2009 D.E.R.N.S. - U.E.R.E.

A.F.S.S.A Reçu le 24 FEV. 2010 10-135 D.E.R.N.S

Subject Health risks related to the installation, maintenance, use and abandonment of renewable energy systems in catchment protection zones for water intended for human consumption

Ref. /No.: No. 100006 (file number to be referenced in all correspondence)

By transposing Directive 2001/77/EC of 27 September 2001 into French law with the Planning Act that establishes guidelines for energy policy (POPE Act of 13 July 2005), France has committed to developing renewable energy to reduce its dependence both on energy and the supply of raw materials, and to reduce its greenhouse gas emissions (under the Kyoto Protocol).

With the POPE Act, France has set national objectives that include:

- to increase from 15% to 21% the share of national electricity consumption from renewable sources. This will come from wind, biomass, and to a lesser extent, hydroelectricity;
- to increase by 50% heat production from renewable sources, such as geothermal energy, by 2015.

It also adopted the objectives of the Grenelle Environment Round Table which advocate increasing the share of renewable energies in final energy consumption (to 23% by 2020).

Confronted with the increasing number of studies of renewable energy installations and the search for suitable land on which to establish these production sites, the catchment protection zones (CPZs) used for the production of drinking water offer the advantage of significant site coverage (several tens of hectares) without necessarily competing with agricultural activity. As such, the Departmental health and social services authorities (DDASS) are increasingly being petitioned by developers and communities that wish to exploit these zones.

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14, avenue Duquesne – 75 350 Paris 07 SP
www.sante-sports.gouv.fr

In order to evaluate these applications, the DDASSs rely on the provisions of the prefectural order of the Declaration of Public Utility (DPU) of the CPZs, where available, which, pursuant to Article R. 1321-13 of the Public Health Code, stipulate that

- for the inner protection zone: “*works, installations, activities, disposals, structures, facilities or land uses that may lead to pollution that renders the water unfit for human consumption are prohibited. Other works, [...] may be subject to requirements, and are subject to specific monitoring.*”;
- for the outer protection zone: “*works, installations [...] that, considering the nature of the land, pose a risk of pollution to abstracted or transported water, owing to the nature and quality of pollutants associated with these activities [...] or the extent of the surfaces that they occupy, may be regulated.*”

However, given the increasing number of applications for renewable energy installations, many DDASSs have asked the DGS for an opinion in order to establish a national health position and to incorporate new provisions in future DPU orders for CPZs, as necessary.

For this reason, the Directorate General for Health wishes to have an assessment of the health risks associated with the installation, maintenance, operation and abandonment of various installations using renewable energy (geothermal heat pumps, solar panels, wind turbines, etc.) in inner and outer catchment protection zones or, failing that, close to the intake point when these boundaries have not been defined by statute, according to the nature of the land and the hydrogeology. This risk assessment shall be accompanied by proposals for appropriate control measures to be implemented, if prohibition of their use is not justified.

I further state that this Request concerning the:

REQUEST FOR THE ASSESSMENT OF HEALTH RISKS RELATED TO THE INSTALLATION, MAINTENANCE, OPERATION AND ABANDONMENT OF RENEWABLE ENERGY RECOVERY SYSTEMS IN CATCHMENT PROTECTION ZONES FOR WATER USED FOR THE PRODUCTION OF DRINKING WATER

is registered at the Directorate General for Health under the number: 100006

Kindly send me your opinion on this matter within a period of 12 months from the date of receipt of this letter.

[Signature]
Jocelyne BOUDOT
Deputy Director of Environmental and Food Risk Prevention

2/2
14, avenue Duquesne – 75 350 Paris 07 SP
www.sante-sports.gouv.fr

Annex 2: Regulatory and other provisions applicable to geothermal energy

Regulatory provisions

The installation of systems using geothermal energy is primarily regulated by the French Mining and Environmental Codes, local authorities and their by-laws.

Mining Code
In accordance with Article 131 of the Mining Code, any survey, underground or excavation work (for any purpose) at depths greater than 10 m requires notification of the Regional Directorate for the Environment, Land-Use Planning and Housing (DREAL) and must be listed in the Subsoil Database (BSS).

In addition, prospecting for and exploiting of geothermal deposits are subject to the following provisions:

- high-temperature geothermal energy (temperature >150°C at the surface and depth of >100 m): requirement to obtain an exclusive prospecting licence by Ministerial Order and a concession by decree in Council of State (See Titles II and III of the French Mining Code, Decrees Nos. 2006-648 and 78-498 as amended),
- low-temperature geothermal energy (temperature <150°C at the surface and depth of >100 m or heat input >200 therms/h): requirement to obtain a prospecting and operating licence, issued by the prefecture (See Articles 98 to 103 of the French Mining Code and No. 78-498 as amended),
- low-temperature, shallower geothermal energy (temperature <150°C at the surface and depth of <100 m and heat input <200 therms/h): exemption from mineral title and reporting requirements (See Decree No. 78-498 as amended).

In addition, the initiation of projects for prospecting and exploiting geothermal deposits is subject to authorisation under Article 83 of the Mining Code.

Environmental Code
According to Articles R. 214-1 and in accordance with the French Environmental Code, subject to authorisation or declaration by the prefecture, the following operations may be undertaken for the purpose of exploiting geothermal deposits:

- drilling of water not intended for household use (Section 1.1.1.0): declaration;
- groundwater abstraction (Section 1.1.2.0.):
    - volume abstracted ≥ 200,000 m^3/year: authorisation,
    - volume abstracted >10,000 m^3/year, but < 200,000 m^3/year: declaration;
- water abstraction in specific areas of hydrological imbalance, known as water distribution zones (Section 1.3.1.0.):
    - capacity ≥ 8 m^3/h: authorisation,
    - in other cases: declaration;
- reinjection into the same groundwater of water abstracted for geothermal energy (Section 5.1.1.0.):
    - total reinjection capacity ≥ 80 m^3/h: authorisation,
    - total reinjection capacity > to 8 m^3/h but < 80 m^3/h: declaration;
- prospecting for and exploiting of geothermal deposits (Section 5.1.2.0.): authorisation.

Furthermore, the Ministerial Orders of 11 September 2003 establish the minimum technical requirements for undertaking a project subject to declaration or authorisation under the Environmental Code in keeping with the protection of underground water.

In addition, groundwater heat pumps are no longer subject to reporting requirements or authorisation under Section 2920 of the legislation on installations classified for the protection of the environment (ICPEs) [Decree No. 2010-1700 of 30 January 2010].

Thus, geothermal operations are covered under:

- the Mining Code if they exploit groundwater considered to be a geothermal deposit under the Mining Code,
- the Environmental Code if they exploit groundwater that is not considered to be a geothermal deposit.

However, any authorisation or declaration obtained under the Mining Code is valid for authorisation or declaration under the Environmental Code (Decree No. 2006-649 of 2 June 2006).

Local Authorities General Code

As of 1 January 2009 and pursuant to Article L. 2224-9 of the Local Authorities Code, any private individual using or wishing to set up a structure for the abstraction of underground water (wells or boreholes) for domestic use (abstraction <1000 m^3/year) must declare this project or its proposal at the town hall (Decree No. 2008-652 of 2 July 2008 and Ministerial Order of 17 December 2008).

In addition, concerning discharges, Article L. 2224-12 of the Local Authorities Code states: “*Municipalities and groups of local communities, according to the opinion of the advisory committee for local public services, shall establish for each water or sanitation service for which they are responsible, service regulations defining, according to local conditions, what the service shall provide as well as the respective obligations of the operator, subscribers, users and owners”.* Thus, local regulations define the conditions for handling discharges. For example, some stipulate that discharges into the wastewater system of effluents with a temperature above 30°C and water used in thermal treatment plants or air conditioning plants, are prohibited. In addition, some regulations specify that groundwater, spring water, discharges or system drainage from thermal treatment or air conditioning plants are not considered to be rainwater and should not be released into the sewer and storm drainage systems.

Technical standards, guidelines, certifications

The installation of systems using geothermal energy entails compliance with certain technical requirements. Current standards include French (NF X10-970, NF X10-999, NF X10-980, prNF X 10-950 and prNF X 10-960), German (VDI 4640 - Part 1-4 and DIN 8901), Swiss (SIA 384/6), etc., and others are being developed in a number of countries (Sanner 2008).

In addition, drillers can follow the French quality scheme, “*QualiForage*”, that specifically commits to conducting operations according to best professional practices (See the list and map of approved drillers at the website www.geothermie-perspectives.fr).

HP fitters can follow the French “*QualiPAC*” scheme and comply with its benchmarks, criteria and quality charter.

Specific provisions for the installation of renewable energy systems within protection zones in other countries

Germany

On 2 June 2010 the [German Technical and Scientific Association for Gas and Water] (DVGW[15]) published a position paper on geothermal energy (on all types of use to a depth of up to 400 metres) in the catchment zones of water intended for human consumption. It highlights the risks incurred for underground water, especially with respect to the potential for pollution by additives used in drilling, cross-contamination of different aquifers, leakage of heat transfer fluids and alterations in the composition of underground water due to heat loss or gain. It also considers the cumulative effects due to a large number of installations and recommends:

1. that geothermal facilities be subject to a declaration with the specialised competent authorities and obtain its authorisation;
2. the use of qualified independent experts (with a knowledge of the technical rules and regulations in geology/hydrogeology, drilling operations, geothermal use, etc.);
3. that geothermal energy operations give priority to the protection of the water table and prohibits their use in:
    - karst and heavily fissured areas (permeability >10^{-2} m/s),
    - aquifers with a well-defined multilayer system or substantial differences in pressure,
    - artesian aquifers,
    - mining areas with a potential risk of subsidence,
    - active tectonic areas,
    - areas in which underground waters corrode injection materials,
    - areas with gas-bearing strata,
    - contaminated sites and their downstream areas,
    - areas where geothermal energy has been fully drawn down;
4. against exploiting geothermal energy in protection zones I[16], II[17] and III/IIIA[18] of catchments of water intended for human consumption. Exceptions will only be made, on a case-by-case basis, depending on the hydrogeological conditions, in protection zones IIIB[15] and only if the heat transfer fluids used are not hazardous to water;
5. that the competent authorities develop plans for using geothermal energy to avoid mutual pollution and overuse of the aquifer;
6. that the selection of a geothermal site be subject to careful scrutiny (geotechnical data, other facilities using underground water, etc.);
7. that the building of the installations be performed by specialised licensed contractors;
8. that building materials and consumables not be hazardous to underground water;
9. sealing the annulus of the wellbores around the probe;
10. careful monitoring of site construction and operation and submission to the competent authority of detailed documentation of all operations performed;
11. that a statement of liability in the event of pollution be required from the operator of the geothermal installation;
12. that faulty or decommissioned installations be dismantled according to best professional practices.

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[15] *Deutsche Vereinigung des Gas- und Wasserfaches.*

[16] *Zone I: area extending 10 metres around the catchment, equivalent to the French immediate protection area.*

[17] *Zone II: area extending 100 metres around the catchment, corresponding to an isochronous transfer of 50 days (only suitable for porous media purposes), equivalent to the French inner protection area.*

[18] *Zone III: area comparable to the French outer protection area, subdivided into porous media in zone IIIA (area extending 2 kilometres around the catchment) and IIIB (zone extending beyond 2 kilometres).*

Switzerland (Canton of Bern)

In order to preserve the quality of the underground water and protect other environmental assets, the Swiss Office for Waste and Water (OED) has developed a map that can be viewed on its website (www.be.ch/oed, under the heading related to 'geothermal probes') specifying the areas and zones where the installation of geothermal probes is permitted in the canton of Bern, whether their depth is restricted or further investigation is needed (Tschumper 2009). The installation of geothermal probes is prohibited:

1. in the protection areas of unconfined groundwater intended for use as drinking water (sector A_u and some areas of sector B). However, exemptions for installing them in some areas on the periphery of sector A_u may be obtained if the water table is lower, on the basis of investigations conducted by geologist consultants. The depth of the boreholes may be restricted;
2. in regions with a large water table or groundwater storeys. More detailed investigations are needed to authorise them in these areas;
3. in areas characterised by karst rock (limestone or gypsum) or karstic phenomena such as sinkholes. Areas exempted from this prohibition include those with a thick landfill cap, composed of loose rock and sandstone molasse in which probes are permitted, but with a limited depth;
4. in known or potential landslide areas;
5. in artesian water areas. However, permission may be granted after further study;
6. in areas that may contain natural gas;
7. in polluted sites (old waste disposal sites, accident sites); further investigations are necessary to authorise them in activity areas, industrial zones, and firing ranges.

Since underground pipelines and installations have not been taken into account in preparing this map, the project owner or manager is responsible for compiling the necessary information.

More generally, in Switzerland, all devices using energy from the ground and subsoil (open and closed systems, horizontal or vertical exchangers) are prohibited in immediate (S1) and inner (S2) protection zones for groundwater used to supply drinking water and may be authorized on a case-by-case basis in outer protection zones (S3) (OFEFP, 2004).

Others

In the Netherlands, some provinces apply the precautionary principle and prohibit open vertical geothermal systems in CPZs (Bonte, 2011a).

Annex 3: Regulatory and other provisions applicable to solar photovoltaic panels

Regulatory provisions

The installation of solar power plants is regulated primarily by the Environmental and Urban Planning Codes and their by-laws along with regulations on the production of electricity (connection, purchase, electrical equipment compliance) (Decree No. 2009-1414 of 19 November 2009 and Circular of 18 December 2009).

<u>Urban Planning Code</u>
Ground-mounted solar installations are subject to prior notification (PN) or building permits (BP), according to their capacity to produce electricity, their above-ground height, their location and the gross floor area (GFA) of additional buildings (See Articles R. 421-1, R. 421-2, R. 421-9, R. 421-11 and R. 421-17).

The PN or BP obligation depends on the peak power of the installations (See Table VIII).

Table IX: Regulatory obligations

	<3 kWc	3≤ kWc ≤ 250	>250 kWc
Ground-mounted solar power plant	No formal requirements if outside the protected zone[19] and above-ground height <1.8 m	Prior notification or building permit if in a protected zone	Impact study, public hearing and building permit

The PN or BP obligation is not always related to the installation of photovoltaic panels, but may concern the construction of additional buildings housing the electrical equipment. The submission criteria for land-use approval are those of general regulations:

- BP for all construction connected with the plant, creating a GFA >20 m^2 or a height of >12 m and 2 m^2 of GFA,
- PN of works, for all construction creating a GFA of >2 m^2 or exceeding 12 m in height,
- development permit, if the plant requires elevations and undercutting of at least 2 m in height over an zone of >2ha.

While buried electrical cables are exempted from official planning code requirements, power lines with voltage of >63 kV must be covered by a BP and those with voltage of <63 kV by a PN.

Any project, whether or not it requires a PN or BP, must comply with general urban planning rules (Article R. 111-21).

In addition, the Circular of 18 December 2009, reaffirms the priority given to incorporation of solar installations in buildings, limits the possibilities of ground-mounted installations in agricultural areas, pursuant to Article R. 111-14 of the Urban Planning Code and, notes that these projects are still subject to other legislation, such as that for water.

[19] *Protected areas are those around historical monuments, listed and classified sites, conservation areas and areas of protected urban and rural architecture heritage.*

However, new provisions concerning the preservation of agricultural land were introduced by Act No. 2010-874 of 27 July 2010, thus buildings and installations required for community facilities may be approved in natural, agricultural or forest areas, under certain conditions.

Environmental Code

Under the French Environmental Code, an impact study and public hearing are mandatory for ground-mounted projects with a peak power of over 250 kilowatts (kWc) (See Articles R. 122-8 and R. 123-1 – Annex I).

The French Ministry of Ecology, Sustainable Development, Transport and Housing has published a guide to conducting impact studies of photovoltaic ground-mounted installations (MEDDTL 2011). This guide specifies that a hydrogeological expert appraisal is to be conducted for any installation within the protection zones (inner, outer) of a water resource, and that the effects on runoff water during operations (altering flows, pollution risks due to materials and equipment) are to be analysed, etc.

In addition, solar power plants may be subject to the Water Act (Article R. 214-1 of the Environmental Code) and to declaration or authorisation under the following sections:

- Section 2.1.5.0. (discharge of rainwater into surface freshwater or on the ground or in the subsoil). If the total area of the project (increased to include the area corresponding to the portion of the natural catchment area whose flows are intercepted by the project) is more than one but less than 20 hectares, the installation shall require a declaration. If the total area of the project exceeds 20 hectares, then authorisation is required;
- Section 3.2.2.0. (installations, structures, embankments in the high-flow channel of a watercourse). If the subtracted area is more than or equal to 400 m^2 but less than 10,000 m^2, the installation shall require a declaration. If the subtracted area is more than 10,000 m^2, then authorisation is required;
- Section 3.3.1.0. (draining, watering, sealing, filling of wetlands or marshes). If the dry area is more than 0.1 ha but less than one hectare, the installation shall require a declaration. If the dry area is more than or equal to one hectare, then authorisation is required;
- Section 3.3.2.0. (construction of drainage systems). If the drainage area is more than 20 ha but less than 100 ha, the installation shall require a declaration. If the drainage area is more than 100 ha, the installation shall require authorisation.

Law on electricity

Installation projects require authorisation to operate from the Ministry of Sustainable Development if they have power greater than 4.5 MWc or a declaration if they have power greater than 250 kWc and less than 4.5 MWc. They are deemed declared if they have power less than 250 kWc (Articles 6 to 9 of Act 2000-108 of 10 February 2000 and Article 6.1 of Decree No. 2000-877 of 7 September 2000).

Technical standards, guidelines, certifications

Since 1 January 2011, photovoltaic installations connected to the public distribution system must conform to the UTE guide C 15-712-1, which establishes the rules for the design, installation and monitoring of photovoltaic systems in addition to the applicable standards for different equipment.

Annex 4: Regulatory and other provisions applicable to wind turbines

Regulatory provisions

The installation of a wind farm is regulated primarily by the Environmental Code and the Urban Planning Code and their by-laws, in addition to regulations on electricity production (Decree No. 2007-1307 of 4 September 2007 and Decree No. 2001-410 of 10 May 2001), on the right to use the maritime public domain in the case of offshore projects, and on controlling ambient noise (Articles R. 1334-32 to R. 1334-35 of the French Public Health Code and Ministerial Order of 5 December 2006). In addition, the Circular of 3 March 2008 requires a study on possible disruption of radar. Whether or not the installation project is located in a wind development zone (*ZDE*), it is subject to the same procedure.

<u>Environmental Code</u>
Land projects with masts over 50 metres in height are subject to an environmental impact assessment (Article R. 122-8) and a public hearing (Article R. 123-1 – Annexe I). Projects with masts below or equal to 50 metres in height are not subject to impact assessments (Article R. 122-5), but require an impact statement (Article R. 122-9). Wind turbine authorisation is under the jurisdiction of the regional prefect (Decree No. 2009-496 of 30 April 2009 and Circular of 3 September 2009).

The French Ministry of Ecology, Energy, Sustainable Development and the Sea has published methodological guides specifically on impact assessments of these types of projects (MEEDDM 2010). The 2010 Guide states that ‘*installation of a wind turbine is prohibited in ImPZs, and feasible in IPZs, according to recommendations*’.

The lifespan of a wind farm is estimated at 20 years and, according to the Environmental Code, the operator of the facility is responsible for dismantling it and restoring the site at the end of operations.

<u>Urban Planning Code</u>
Wind turbines with a mast higher than 12 metres must have a building permit.

<u>Wind development zones (*ZDEs*)</u>
The POPE Act stipulates that a wind turbine, small or large, must be located in a *ZDE* to benefit from the commitment to purchase the electricity produced. A *ZDE* is defined by its boundary and the minimum and maximum power that can be installed therein.

The existence of zones of protected urban and rural architectural heritage (*ZPPAUP*) or zones of ecological interest for fauna and flora (*ZNIEFF*) may prevent the creation of a *ZDE* or the installation of wind farms.

The proposed installation of a wind farm in a *ZDE* does not imply its final approval.

<u>Expected changes in regulations</u>
Since the law on national commitment to the environment, called Grenelle 2, provides for stronger constraints on the installation of wind turbines as of 12 July 2011, some wind turbines will be subject to legislation on installations classified for environmental protection. The obligation to dismantle the facility and restore the site should likewise be required, the foundations should be

removed up to one metre deep and only the cables close to the machinery and equipment are to be removed from the ground (within a 10 m radius of the installations).

In addition to the ZDEs, regional wind schemes (SREs) are planned, indicating zones where it is possible to establish new ZDEs. The regional prefect will be responsible for preparing them.

Technical standards, guidelines, certifications

The current series of Standards NF EN 61400 (wind turbines) and especially Standards NF EN 61400-1 and 2 pertain to the design requirements.

Annex 5: Regulatory and other provisions applicable to products used in renewable energy systems

Regulatory provisions

Heat transfer fluids

There is a specific regulation for heat transfer fluids that may be used in direct exchange heat treatment facilities for water intended for human consumption.

Article R. 1321-57 of the CSP states that '*domestic systems must not be permitted, because of conditions for their use, particularly as a result of backflow phenomena, to disrupt the operation of the system to which they are connected or cause contamination of the water distributed in the domestic distribution system*'.

The Circular of 26 April 1982 amending the departmental health regulation (RSD) and more specifically, its Article 16-9, stipulates that heat transfer fluids that have received a favourable opinion from the French High Council for Public Heath (CSHPF) may be permitted in direct exchange facilities. In addition, a technical order of the French Scientific and Technical Centre for Building (CSTB)[20] defines the rules for compliance of heat exchangers and their installations in this Article (nature of the materials, pressure of the drinking water inside the heat exchanger always greater than the pressure of the fluid vector, existence of a method for detecting possible leaks, signs to indicate the nature of the heat transfer fluids used, etc.).

DGS/PGE/1.D. Circulars Nos. 942 of 2 July 1985 and 357 of 2 March 1987 specify the classification of heat transfer fluids that may be permitted in facilities operating in single exchange (lists A, B and C):

- list A: heat transfer fluids that may be used in direct exchange heat treatment facilities for water intended for human consumption,
- list B: list of additives that may be introduced into heating systems for heat treatment of water intended for human consumption (direct exchange),
- list C: heating fluids and lubricants that may be used in direct exchange heat pumps.

Following on from AFSSA (2001 to 2010), according to the conditions defined in June 2008 (AFSSA 2008b), ANSES now reviews applications for inclusion in lists "A" and "C" of heat transfer fluids that can be used in direct exchange heat treatment facilities for water intended for human consumption.

ANSES's assessment aimed to protect consumers of WIHC in case of incidents and/or accidents, and to prevent the sale of the most toxic heat transfer fluids. The majority of heat transfer fluids that have received a favourable opinion from ANSES are made from propylene glycol.

However, this provision does not by itself ensure user protection. It is important to use fluids whose technical quality and efficacy (anti-corrosion and anti-freeze properties, for example) have been tested (ATEC of the CSTB for example) and comply with technical rules during the design, installation, maintenance and dismantling of systems containing heat transfer fluids to avoid incidents and/or accidents.

[20] *CSTB technical order No. 235 of December 1982 – Specification No. 1815.*

Refrigerants
The most commonly used fluorinated refrigerants are made from chlorofluorocarbon (CFC), hydrochlorofluorocarbon (HCFC) and hydrofluorocarbon (HFC). They are covered by the two international protocols: Montreal for ozone-depleting substances (ODSs) and Kyoto for fluorinated greenhouse gases (FGGs), whose provisions are included in Regulation (EC) No. 2037/2000 on ODSs and Regulation (EC) 842/2006 on FGGs. CFCs, HCFCs and HFCs used as refrigerants in refrigeration and air conditioning equipment are also subject to the provisions of Articles R. 543-75 to R. 543-123 of the French Environmental Code.

These provisions:

- ban CFCs from the maintenance of equipment using these fluids, refrigerants packaged in containers that do not allow their recovery, and those that do not work with an extraction device;
- aim to limit fluid emissions into the atmosphere by:
  - mandatory inspections for leaks (annually, for equipment containing more than two Kg of fluid, every six months for equipment containing more than 30 Kg of fluid and at least one month after an equipment leak occurs) and keeping a so-called 'intervention' record specifying the nature and volume of recovered and/or reintroduced fluid, for three years,
  - a ban on venting into the atmosphere except when necessary to human safety,
- require operators of refrigeration and air conditioning equipment to use companies registered by the prefecture for the following operations: commissioning of an installation, maintenance and repair, testing for leaks, draining).

Other fluids not covered by these regulations, such as ammonia and CO_2, can also be used.

Irrespective of the refrigerant used, some installations may be subject to declaration or authorisation under the legislation concerning installations classified for the protection of the environment (ICPEs).

Technical standards, guidelines, certifications

Heat transfer fluids
It should be emphasised that the technical quality of heat transfer fluids is just as important as their compliance with health requirements (anti-corrosion and anti-freeze properties, for example). Some heat transfer fluids are issued with a technical assessment (ATEC)[21] when their performance has been certified by the CSTB. Obtaining authorisation from the Ministry of Health following a favourable opinion from ANSES is a mandatory criterion for granting an ATEC for a fluid intended for use in direct exchange installations for the production of domestic hot water.

According to French Standard NF X 10-970, the liquid heat transfer fluid of a vertical geothermal probe should have no impact on the environment in the event of leaks. It must be at least 98% biodegradable (for example, a mixture of water and monopropylene glycol or equivalent) and be of food grade.

[21] *ATECs are issued by a special group composed of experts in the field, overseen by the CSTB, providing an opinion on the suitability of a non-conventional product (or system) intended for use in construction.*

Annex 6: Summary of experts' public declarations of interest in the field of the request

REVIEW OF THE SECTIONS OF THE PUBLIC DECLARATION OF INTEREST (PDI)

IF	Financial interest in the capital of a company
LD	Lasting or permanent relationship (work contract, regular payment, etc.)
IP	Occasional services (scientific research, expert reports, consulting work, conferences, seminars, training activities, etc.)
SR-A	Other special unpaid relationships (participation on Boards of Directors or scientific boards in an organisation, company or professional body)
VB	Activities resulting in a payment to the budget of an organisation of which the expert is in charge or has scientific responsibility (corresponding to Section 3 of the PDI)
SR	Other unpaid relationships (Relatives who are employees of corporations covered by the law – see subsection of the PDI notice; other interests considered prejudicial to the expert's impartiality)

SUMMARY OF PUBLIC DECLARATIONS OF INTEREST OF MEMBERS OF THE EXPERT COMMITTEE (CES) IN THE FIELD OF THE REQUEST

LAST NAME **ANSES analysis:**	**First name** ***Sections of the PDI*** Description of the interest *If declared relationship*	**Date of the declaration of interest**
ANDRES **ANSES analysis:**	**Yves** *No declared relationship to the field of the request*	09/09/2010 16/04/2011
BOUDENNE **ANSES analysis:**	**Jean-Luc** *No declared relationship to the field of the request*	26/07/2010 07/02/2011
CABASSUD **ANSES analysis:**	**Corinne** *No declared relationship to the field of the request*	12/09/2010
CARRÉ **ANSES analysis:**	**Jean** *No declared relationship to the field of the request*	01/09/2009 12/08/2010 22/03/2011
CHUBILLEAU **ANSES analysis:**	**Catherine** *No declared relationship to the field of the request*	08/09/2010 08/02/2011
CORREC **ANSES analysis:**	**Olivier** ***IP*** CSTB: Research work on the technical quality of heat transfer fluids, since 2009 *No potential conflicts of interest with respect to the subject of the request*	25/05/2009 26/09/2010 03/05/2011
DAGOT **ANSES analysis:**	**Christophe** *No declared relationship to the field of the request*	15/10/2008 12/04/2011

DUBROU **ANSES analysis:**	**Sylvie** *No declared relationship to the field of the request*	23/02/2009 09/09/2010 20/04/2011
GOUSAILLES **ANSES analysis:**	**Michel** *No declared relationship to the field of the request*	17/09/2010 18/04/2011
HÉDUIT **ANSES analysis:**	**Alain** *No declared relationship to the field of the request*	20/08/2010 09/02/2011
HUMBERT **ANSES analysis:**	**Jean-François** *No declared relationship to the field of the request*	17/07/2010 03/05/2011
JOYEUX **ANSES analysis:**	**Michel** *No declared relationship to the field of the request*	25/02/2009 05/08/2010 23/04/2011
LE BÂCLE **ANSES analysis:**	**Colette** *No declared relationship to the field of the request*	23/09/2010 03/05/2011
LE CANN **ANSES analysis:**	**Pierre** *No declared relationship to the field of the request*	28/02/2009 08/09/2010 15/03/2011
LEVI **ANSES analysis:**	**Yves** ***IP*** EDF: Board member since 2005 (professional fees) *No potential conflicts of interest with respect to the subject of the request*	08/02/2009 04/09/2010 13/03/2011
MATHIEU **ANSES analysis:**	**Laurence** *No declared relationship to the field of the request*	26/08/2010 27/03/2011
MAZELLIER **ANSES analysis:**	**Patrick** *No declared relationship to the field of the request*	20/03/2009 25/08/2010 27/01/2011
MUDRY **ANSES analysis:**	**Jacques** ***IP et VB*** CEA: WG on underground floods, resulting in payment to the laboratory at the University of Franche-Comté (2008) (0% of the budget) *No potential conflicts of interest with respect to the subject of the request*	26/02/2009 15/09/2010 13/04/2011
PONTIÉ **ANSES analysis:**	**Maxime** *No declared relationship to the field of the request*	27/08/2010 23/02/2011
POURCHER **ANSES analysis:**	**Anne-Marie** *No declared relationship to the field of the request*	02/09/2010 09/02/2011
TARDIF **ANSES analysis:**	**Robert** *No declared relationship to the field of the request*	21/09/2010 08/02/2011
TREMBLAY **ANSES analysis:**	**Michèle** *No declared relationship to the field of the request*	02/09/2010 14/04/2011

WELTÉ **ANSES analysis:**	**Bénédicte** ***IP*** French Scientific and Technical Association for Water and the Environment (ASTEE): Working Group on distribution and protection of the resource since 1990 (No compensation) *No potential conflicts of interest with respect to the subject of the request*	14/01/2009 23/08/2010 10/02/2011

SUMMARY OF PUBLIC DECLARATIONS OF INTEREST OF MEMBERS OF THE WORKING GROUP (WG) IN THE FIELD OF THE REQUEST

LAST NAME **ANSES analysis:**	**First name** ***Sections of the PDI*** Description of the interest *If declared relationship*	**Date of the declaration of interest**
ALCAYDE **ANSES analysis:**	**Gilbert** *No declared relationship to the field of the request*	15/01/2009 08/08/2010
CARRÉ **ANSES analysis:**	**Jean** (Member of the CES on Water) *No declared relationship to the field of the request*	01/09/2009 12/08/2010 22/03/2011
CORREC **ANSES analysis:**	**Olivier** (Member of the CES on Water) ***IP*** CSTB: Research work on the technical quality of heat transfer fluids since 2009 *No potential conflicts of interest with respect to the subject of the request*	25/05/2009 26/09/2010 03/05/2011
HERAULT **ANSES analysis:**	**Sophie** *No declared relationship to the field of the request*	16/02/2009 12/09/2010 30/12/2010
LE CANN **ANSES analysis:**	**Pierre** (Member of the CES on Water) *No declared relationship to the field of the request*	28/02/2009 08/09/2010 15/03/2011
MUDRY **ANSES analysis:**	**Jacques** (Member of the CES on Water) ***IP et VB*** CEA: WG on underground floods, resulting in payment to the laboratory at the University of Franche-Comté (2008) (0% of the budget) *No potential conflicts of interest with respect to the subject of the request*	26/02/2009 15/09/2010 13/04/2011
PEIGNER **ANSES analysis:**	**Patrick** *No declared relationship to the field of the request*	21/02/2009 09/08/2010