GEOENER
Geothermal Energy in the Building & Industry Sectors
Madrid 15-16 October 2008

GEOTHERMAL POTENTIAL OF THE MADRID AREA

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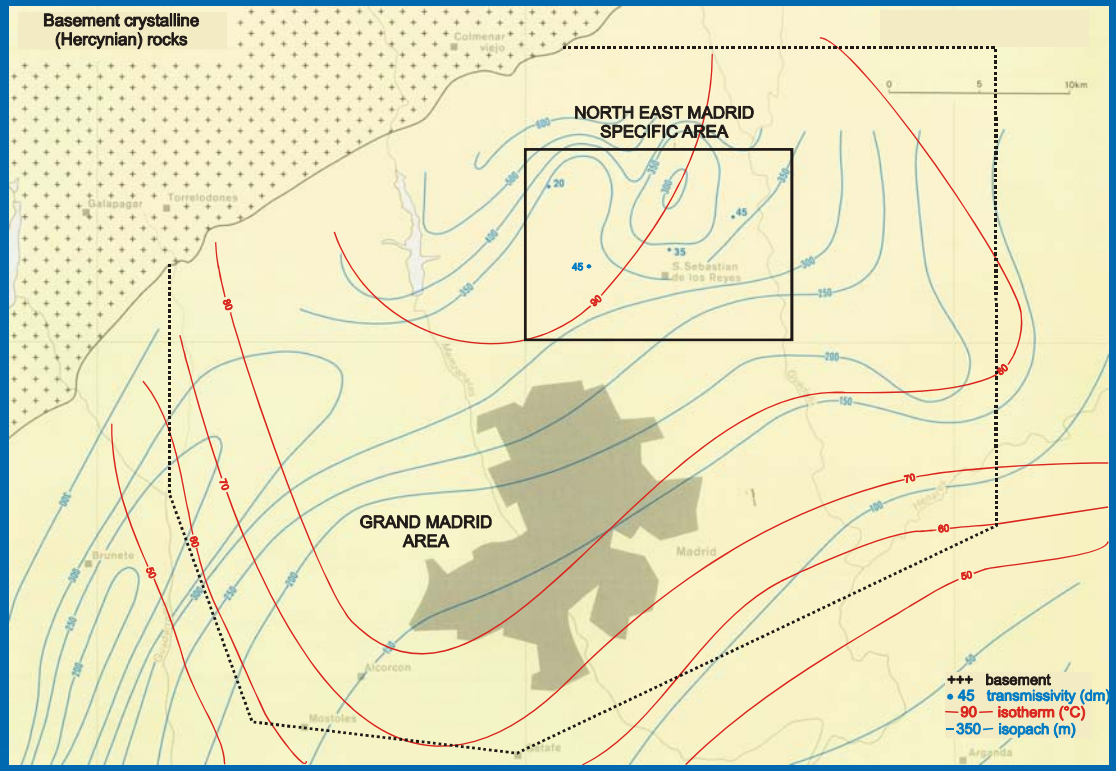
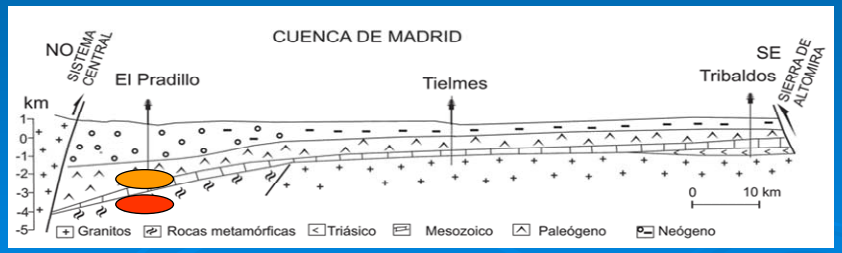
MADRID GEOTHERMAL RESOURCE SETTING

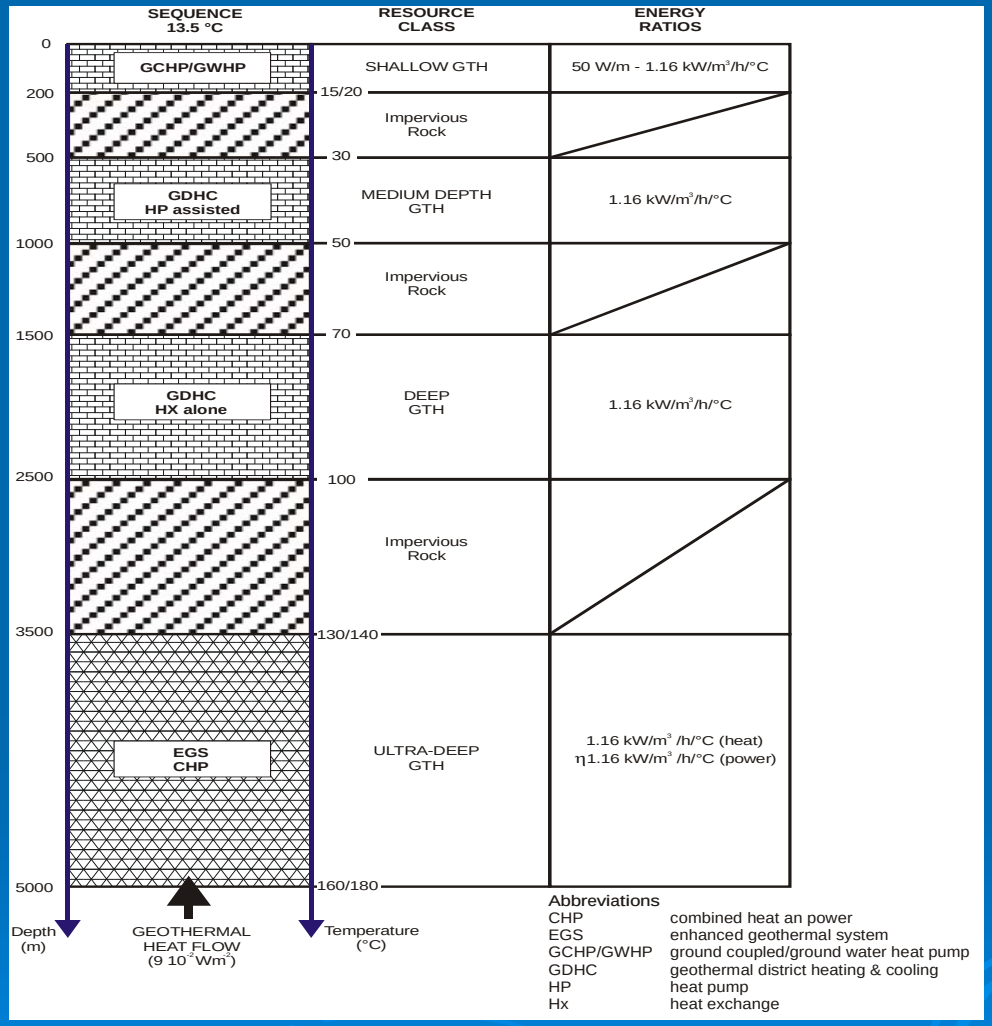


Location of Target Assessment Areas



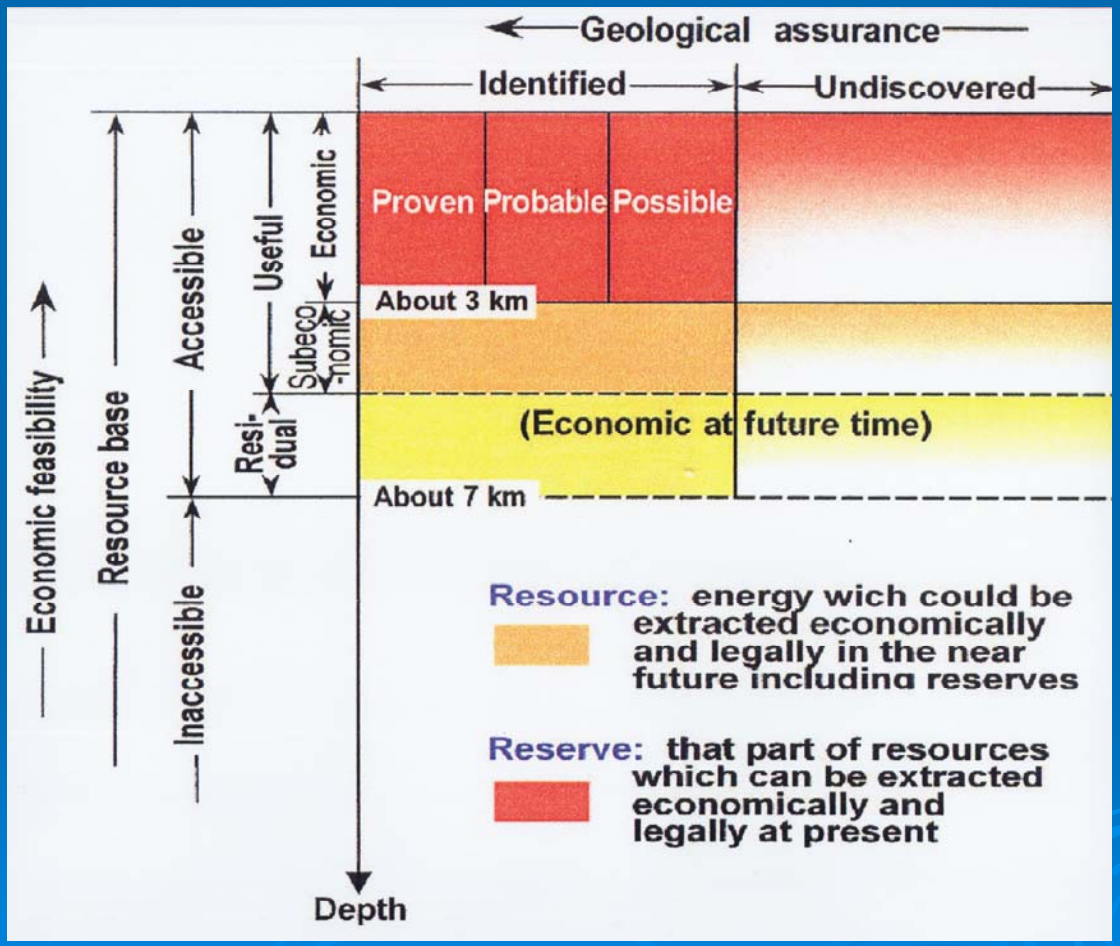
NO-SE CROSS SECTIONAL SKETCH

(Adapted from European Geothermal Atlas & Racero 1988)



GEOTHERMAL RESOURCE CLASSIFICATION VS DEPTH, TEMPERATURE & AQUIFER OCCURENCE

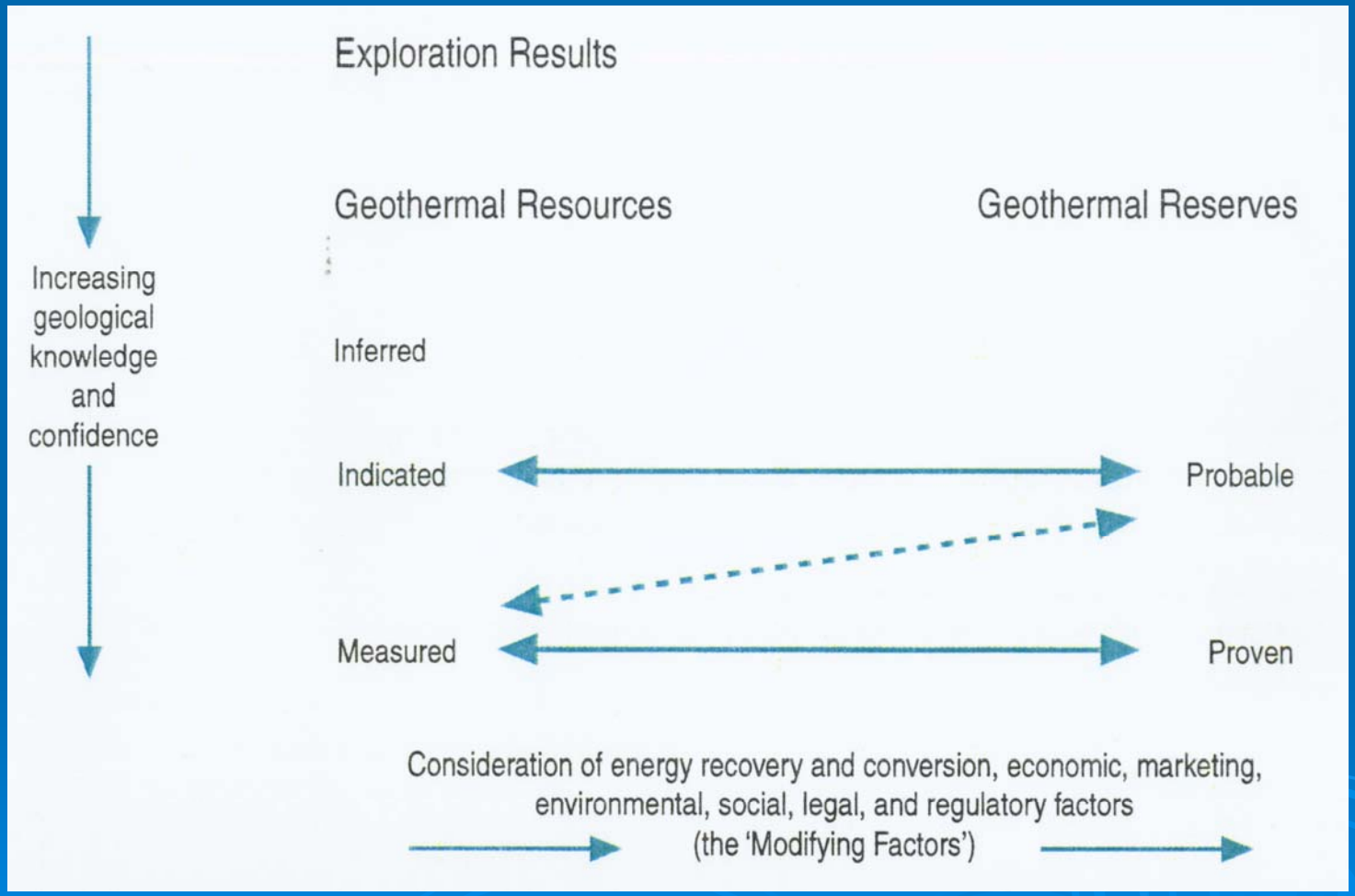
GEOTHERMAL RESOURCE/RESERVE CLASSIFICATION



EU NOMENCLATURE

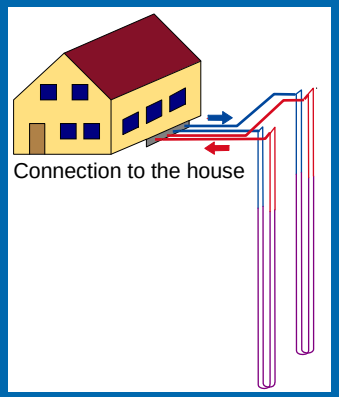
Source: Groundhit

GEOTHERMAL EXPLORATION/RESOURCE/RESERVE INTERACTION

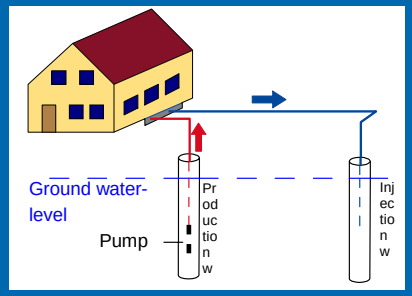


Source: Australian Geothermal Reporting Code (AGCC)

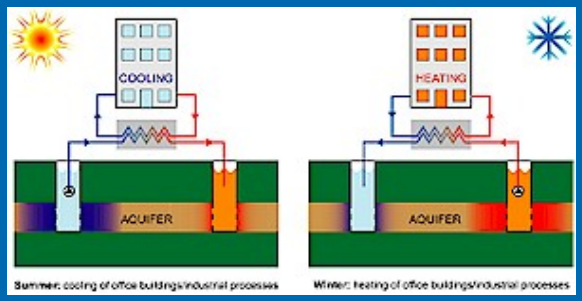
MINING SCHEMES



a. Borehole heat exchanger (BHE)



b. Groundwater doublet (GWD)

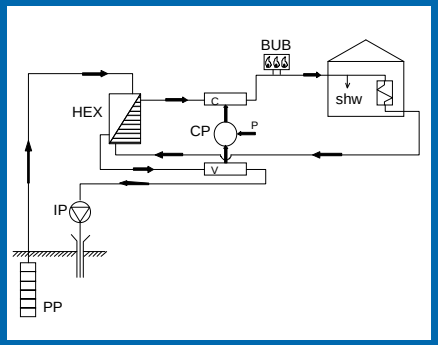


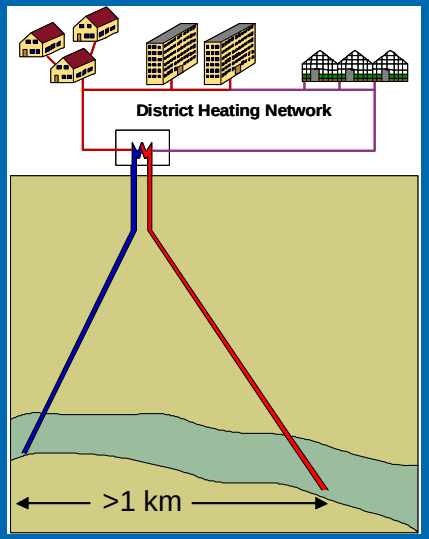
c. Aquifer energy storage (ATES)

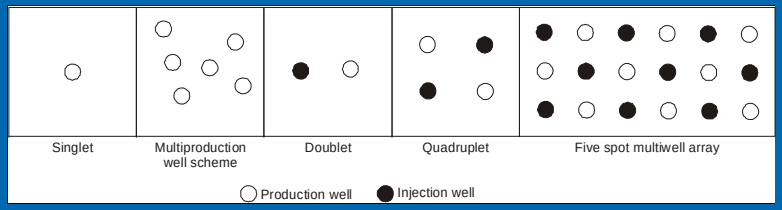
Shallow geothermal (0-200m) GSHPs

Shallow Geothermal Sources

MINING SCHEMES





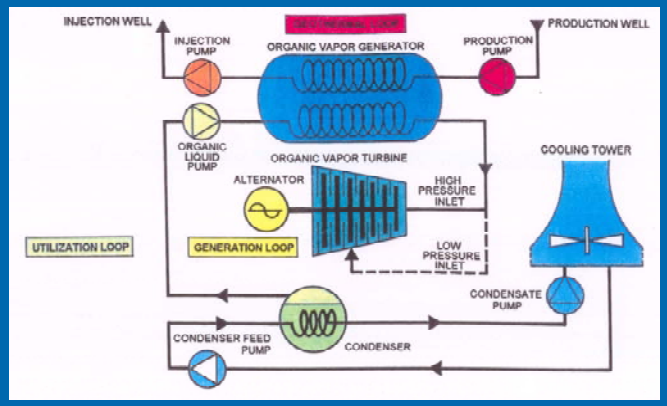


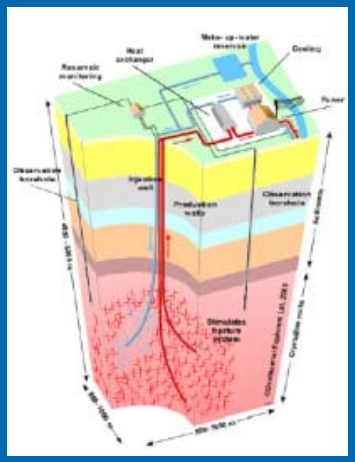
a. Medium depth doublet (heat pump assisted)	b. Deep doublet (heat exchange alone)	c. Multiwell arrays

Medium depth/deep geothermal (1000-2500m)

Medium depths - Deep Geothermal Sources

MINING SCHEMES





a. Organic Rankine Cycle	b. Unconventional (EGS) CHP
Ultra deep geothermal (3500-5000 m)	

Deep - Ultradeep seated Sources EGS

GEOTHERMAL RESOURCE & RESERVE ASSESSMENTS

DEFINITIONS

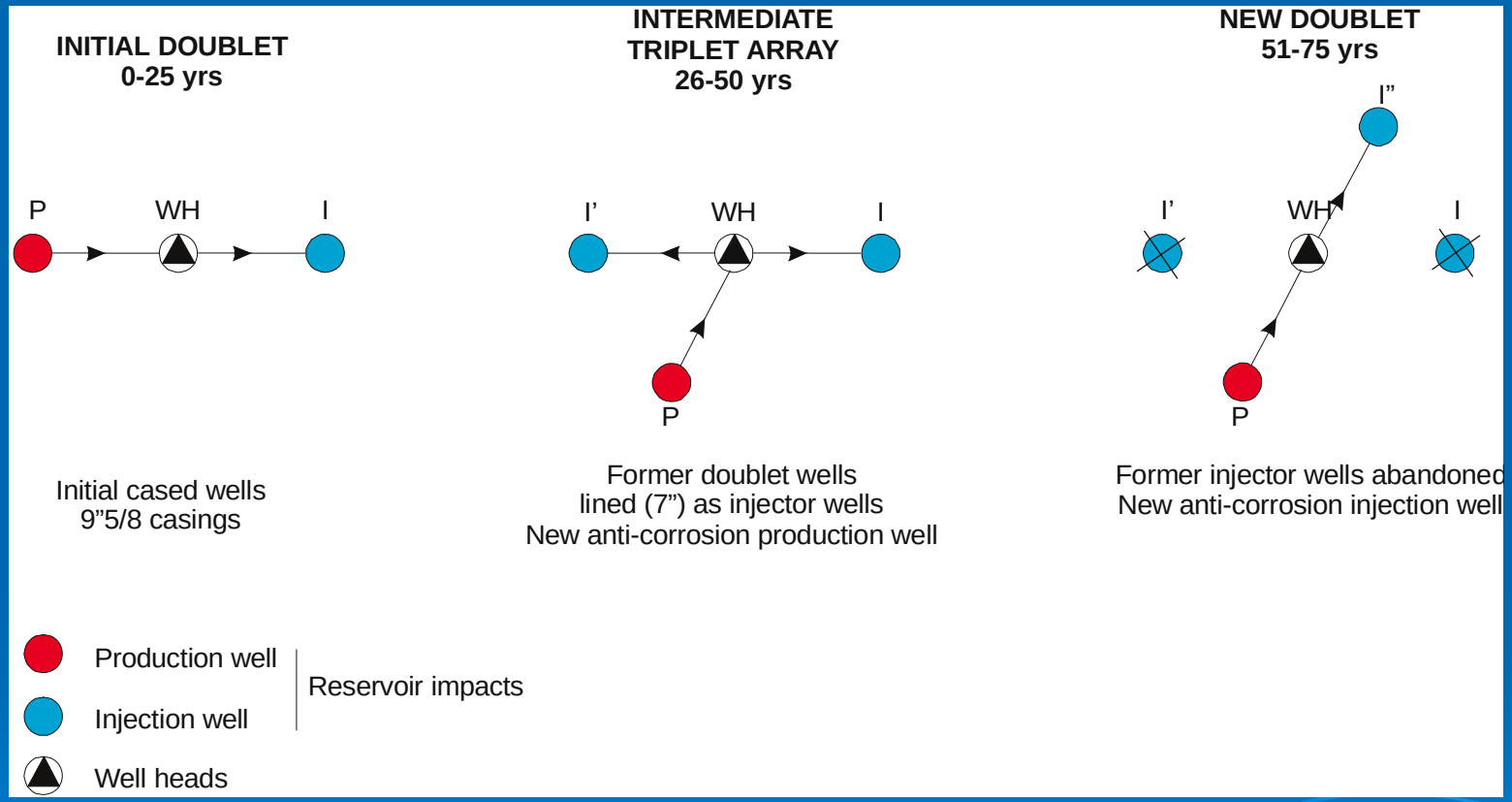
- Heat in place HIP
  $HIP = \gamma_t * Ah(\theta_i - \theta_0)$
- Recoverable heat RCH
  $RCH = \eta\gamma_t * Ah(\theta_i - \theta_r) = r * HIP$
- Heat recovery factor r
  $r = RCH / HIP = \eta(\theta_i - \theta_r)/(\theta_i - \theta_0)$
- Efficiency of the heat extraction scheme η
  $\eta = (q / Ah) * (\gamma_w / \gamma_t) * t^*$
- EGS power (W) and energy supply (E)
  $W = \eta' q' \gamma_w (\theta_i - \theta_c)/3600$
  $E = W * t'^*$

NOMENCLATURE

A = area (m^2)
h = effective thickness (m)
q, q' = flowrates (m^3/h)
r = recovery factor
t^*, t'^* = system life (hrs)
$\gamma_t = \phi\gamma_w + (1-\phi)\gamma_r$ = total (fluid + rock) heat capacity ($kJm^{-3}K^{-1}$)
γ_t, γ_r = rock and water heat capacities ($kJm^{-3}K^{-1}$)
$\theta_i, \theta_0, \theta_r, \theta_c$ = reservoir, mean ground, rejection and condensing temperatures (°K)
η, η' = efficiencies

DEFINITIONS

MINING SCHEMES



Sustaining 75 yrs

System life

ZONE	OVERALL (Grand Madrid)	SPECIFIC (NE Madrid)
AREA (km^2)	**1400**	**150**
VOLUME 5 km depth (km^3)	**7000**	**750**
HEAT FLOW DENSITY (Wm^{-2})	**$9\ 10^{-2}$**	**$9\ 10^{-2}$**
SUBSURFACE TEMPERATURES (°C)		
500 m	35	35
1500 m	60-70	60-70
2500 m	80-100	80-100
5000 m	160-180	160-180
ACCESSIBLE RESOURCE BASE (ARB) 5 km 10^{19} J	**560**	**6.2**
HEAT RESUPPLY		
Power (MWt)	126	13.5
Energy (GWht/yr)	**1130**	**104**
HEAT IN PLACE (HIP) (10^{18} J)		
Shallow GTH	21	2.2
Medium depth GTH	18	3.9
Deep GTH	27	3.1
Ultra-deep GTH	115	13.1
TOTAL	**$181\ 10^{18}$ J**	**$22.3\ 10^{18}$ J**
RECOVERABLE HEAT (RCH) OVER 75 yrs		
Shallow GTH (BHE/GWD) (10^{18} J)	3.3/1	0.35/0.1
Medium depth GTH (10^{18} J)	6.3	1.4
Deep GTH (10^{18} J)	9.5	1.1
Ultra-deep GTH (10^{18} J)	5.8	0.7
TOTAL	**$24.9/22.6\ 10^{18}$ J**	**$3.6/3.3\ 10^{18}$ J**
EXPLOITABLE HEAT (AND POWER) OVER 75 yrs		
Shallow GHT (BHE/GWD) (10^{17} J)	0.36/0.07	0.04/0.007
Medium depth GTH (10^{17} J)	1.3	0.3
Deep GTH (10^{17} J)	4.4	1.1
Ultra-deep GTH CHP (10^{17} J)	1.2	0.3
TOTAL	$7.3/7\ 10^{17}$ J	$1.7/1.7\ 10^{17}$ J
HEAT RESUPPLY (10^{17} J)	3.09	0.33

CONCLUSION

Item	Grand Madrid	NE Madrid
Heat in place (HIP) 10^{18} J	181	22
Recoverable heat (RCH) 75 yrs 10^{18} J	25	3.5
Exploitable heat (and power) (EXH) 75 yrs 10^{17} J	7.3	1.7
Heat resupply (assuming 90mWm^{-2} heat flow density) 10^{17} J	3.09	0.33
EXH / RCH ratio (%)	3	5

FINAL RESOURCE/RESERVE PROJECTED FIGURES