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The Geothermal Resources and Potential in Hanoi Basin, Vietnam

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ABSTRACT

This report describes the geothermal resources and potential in Hanoi basin followed by the results of heat flow and subsurface temperature studies. The not small size 40 km × 14 km of high heat flow anomaly with values more than 100 mW/m^2 was detected in the southeastern part of the basin. The temperature at depth about 3000 m under this anomaly measured in the oil borehole is reached about 140^{0}C - 150^{0}C. This area is expected to the Pre-feasibility study for energy generation.

The geothermic measurements carried out in a large number of the shallow wells in the basin are indicated the stable range of temperature 25-26^{0}C from the depth 15 - 20 m to more than 100 m around year. It is noted that, the Hanoi basin is the biggest energy consumption area in Northern Vietnam. The hot time duration is often more than 8 months in every year with the temperature in the air varied from 30^{0}C to 38^{0}C, so the use of the ground sources heat pump (GSPH) for air conditioning systems can be expected as a measure for saving of the energy consumption.

1. INTRODUCTION

Study area is the largest Cenozoic sedimentary basin in North Vietnam (Fig. 1). The first temperature measurements in drill-holes for oil and gas exploration had been conducted during the years of 1970's. In the years 1991 – 1992 geothermal study was carried out by the Institute of Geological Sciences of Vietnam in collaboration with Siberian Branch of Russian Academy of Science, Texas University, including the temperature measurements in about 40 hydrologic monitoring wells, thermal conductivity of numerous samples had yet measured. These results allowed to estimate the preliminary geothermal characteristics in the Hanoi basin. The south-eastern part of the basin, is identified geothermal anomaly: the temperature at depth about 3000 m in the oil exploration borehole is reached about 140^{0}C - 150^{0}C; gradients are greater 40 mKm^{-1}, heat flow values greater 100 mW/m^2 in comparison 30 mKm^{-1} and 50 mW/m^2 in the rest part of the basin. The total amount of heat down to 4 km beneath the basin estimates about 2.53 × 10^{15} J. The relationship between the geothermal data and regional geological features will be discussed.

Furthermore, in the study area, several hot water sources with temperature 45–50^{0}C in the Quaternary sediments are discovered. Temperature monitoring in shallow wells and a large number of underground water layers from the depths of 15m to 100 m show stable values of 25 -26^{0}C around year. The remarkable low temperature in the shallow ground layers in comparison with the air temperature 30-38^{0}C in summer, can be used for conditioning systems with the purpose of saving energy consumption.

2. GEOLOGICAL SETTING

The Hanoi basin is the landward extension of the Song Hong – Yinggechai and Beibu Wan basins, both of which lie in the Gulf of Bac Bo (Tonkin). The Red River strike-slip fault enters the Hanoi basin from the northwest, splaying into a number faults that are recognized by the geophysical data. The strong subsidence happened during the Cenozoic time as the consequence of activity of strike-slip Red River fault with predominance of normal component in the study region is created the Basin with much thicker layer of sediment and thinner crust (Fig. 2). Inside the basin, the Red River fault splays into at least six major branches. The numerous horst and graben types of structures were formed within the basin. The mentioned above faults may played the role as barriers prevented the groundwater flow or its conduits. Thus, the heat convection caused by water flow may affect the surface expression of vertical heat flow in the basin (Harder et al., 1996).

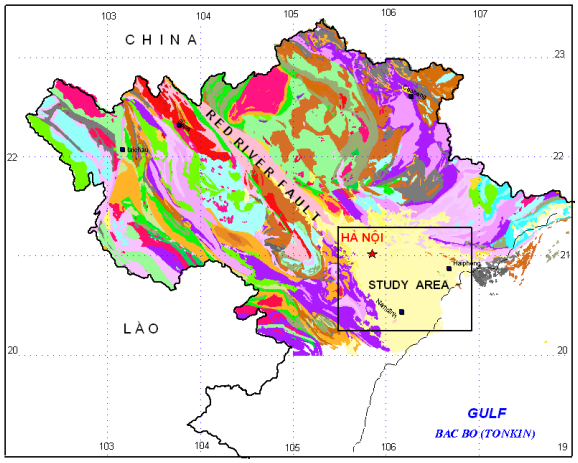

Figure 1: The location of study area – Hanoi basin at the geological map of North Vietnam

The summarized stratigraphic sedimentary sequence of the basin derived from drilling results is indicated the high rate of subsidence during the Cenozoic time (Fig.3-PetroVietnam, 2007). In addition, the complexity of geotectonic evolution is reflected by the strong change of depth to the Precenozoic basement from some hundreds meters in the marginal area to more than 5.5 km in the south-eastern part of the basin.

3. STUDIED GEOTHERMAL RESULTS

3.1 Assessment of geothermal gradient and heat flow

The geothermal study based on the temperature measurements in 16 oil exploration and in 31 hydrological monitoring wells one. Most of the oil exploration wells are concentrated in the southeastern part, some of which reached depth of 3000 m. The hydrological monitoring wells were typically less than 100 m deep (Fig. 4), they penetrate the unconsolidated Quaternary sediments, that is mostly covered the Hanoi basin. In all the wells were

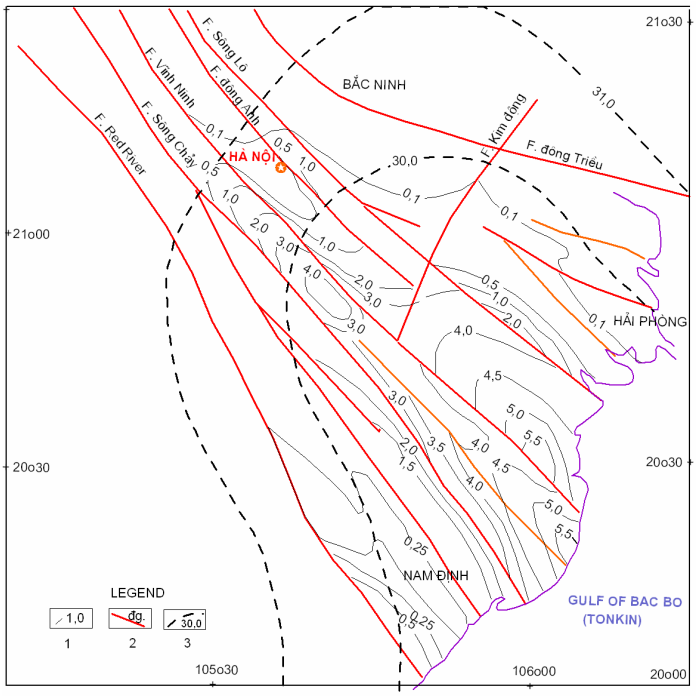

Figure 2: The thickness of Cenozoic sediment and depth of Moho surface in Hanoi basin established by combination of drilling and geophysical data. Contour interval in km. 1 – sedimentary isopach; 2 – tectonic fault; 3 – earth crust thickness.

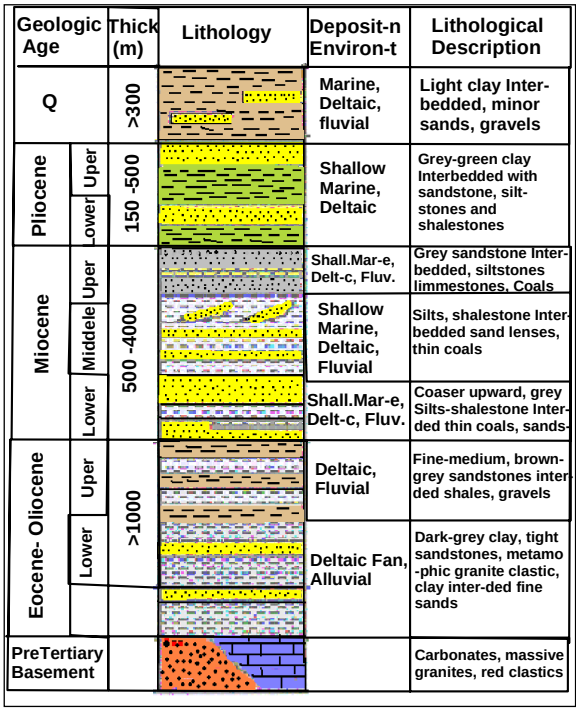

Figure 3: Summarized Cenozoic sediment stratigraphy in Hanoi basin (PetroVietnam, 2007)

conducted the measurements of temperature at different depths as well as the heat conductivities of rock samples. Since that the geothermal gradients and heat flow in the observational points were also calculated.

The typical geothermal parameters for Hanoi basin are demonstrated by the data collected in the deep oil exploration borehole (3200 m) in the southeastern part of the study region (Fig. 5).

Based on these investigated results the preliminary scheme of heat flow distribution on the Hanoi basin was established (Fig. 4). The high heat flow anomaly delineated by the contour-line 100 mW/m^2 is occupied relatively a large area the southeastern part of Hanoi basin. In the central zone of anomaly the heat flow is reached more than 100 mW/m^2, similar to those observed in East Vietnam Sea region and in the other extensional basins in Southeast Asia (Harder et al. 1996). It is noted that, under the anomaly area are distributed very thick Cenozoic sediments, expected to become the geothermal reservoir. The active geothermal regime also is indicated by appearance of hot water sources (t >40^0 C) in a number of shallow hydrologic wells in the different locations of the study area (Fig. 4).

3.2 Assessment of geothermal resource and potential

Based on the correlation of the geothermic activity with the geotectonical and geophysical data, it was believed that geothermal heat could be produced from deep. The analysis of the available data led us to the suggestion: the hot aquifer probably is the sandstone formations of pre-tertiary or Neogen ages at depths from 2 km to more than 3 km. The high water content and a large underground space of distribution are capable of the expected geothermal reservoir. Generally in the Hanoi basin until now the thick sandstone layer of pre-tertiary age is not encontoured, however in its northeastern part in some oil exploration wells the hot water (100^{0}C- 140^{0}C) is detected in the Neogen sandstone with good porosity and permeability at depths of 2000 – 3000 m. The mentioned above condition is encouraged us to think about the investigations for possibility of the geothermal reservoir in the basin.

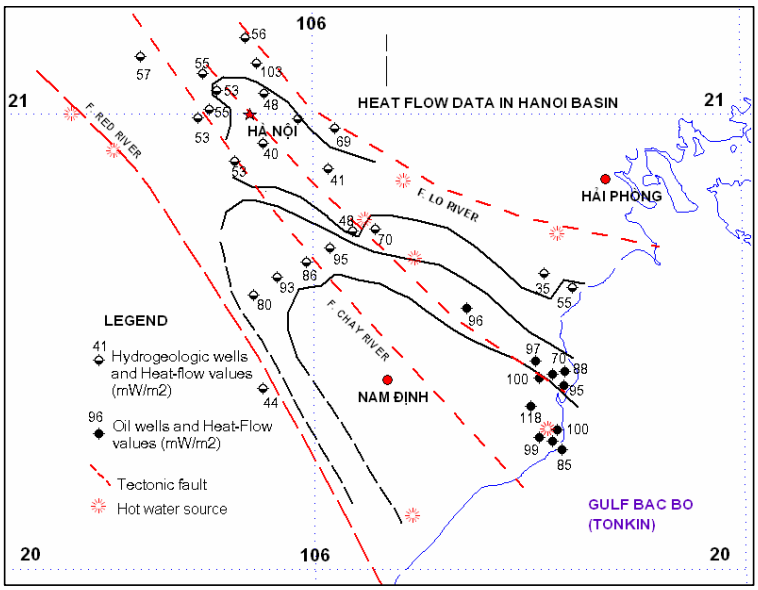

Figure 4: The Heat-flow distribution and hot water sources in the region of Hanoi basin (Doan Van Tuyen et al., 2008)

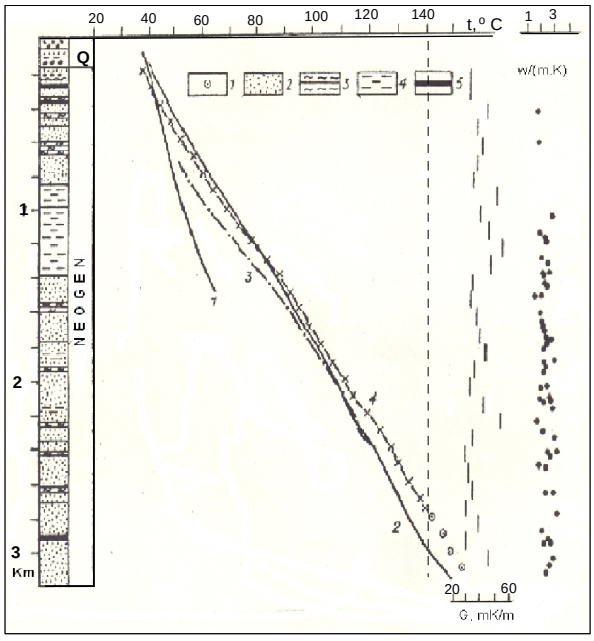

Figure 5: The typical geothermal results in southeastern part of Hanoi basin. 1 -Extrapolated temperature; 2 –sands, sandstone; 3 –silt; 4 – clay; 5 -coals (Duchkov et al., 1992)

Based on regional geological studies (e.g. Tran Nghi et al. 2000) a number of stratigraphic units with a geothermal potential reservoir have been identified. These include the Upper Triassic (T_3n-r *vl*) Van Lang, Lower – Upper Jurassic ($J_{1\text{-}2}$ *hc*) Ha Coi sandstone formations. Other formations may also locally contain potential aquifers, such as fine-medium sandstones, fine sands, gravels of the Eocene-Oligocene Phu Cu, Phong Chau, Dinh Cao, Phu Tien formations in southeastern part of the basin (Fig. 3).

The temperature and mineralization of the hot water in these potential formations increase with increasing depth. The temperature-depth relation is well established as in the Fig. 5, for shallow wells gradient of 3^0C/ 100 m, for depths > 1000 m the gradient about 4^0C/100m. Based on the chemical analysis of the hot water samples collected from 15 wells in the depth range from more than 100m to 3000m the total mineralization is varied from 700 – 1300 mg/l to greater 20,000 mg/l respectively, hot water flow rate is range 30 – 300 m^3 per day (Mineral and thermal water sources of Vietnam, the book was published by Department of Geology and minerals of Vietnam, 1998). Combined all the data about the porosity, permeability, structutre, stratigraphy and geothermal parameters we can see at least two types of the expected geothermal sources: hot water aquifers and faults related to the sandstone formation in the southeastern part of the basin. The other rock formations are also possibly the heat aquifer also, but it is difficult to define due to we have no enough the data, such as permeability, porosity, geothermal parameters etc…

Based on the above descried results the first geothermal assessment for Hanoi basin can be defined by the formulas (Cermak and Ribach, 1982):

Temperature at depth:

$$T(z) = \frac{A_0 b^2}{\lambda}(1 - e^{-z/b}) + \frac{Q_0 - A_0 b}{\lambda} + T_0 \quad (1)$$

Heat contains down to depth:

$$Q = \rho C_p V\{T(z) - T_0\} \quad (2)$$

Where parameters in (1) and (2) are determined from studied results: T_0 is surface temperature, Q_0 – the surface heat flow values, A_0 – the heat production, V – the total volume in the depth interval, C_p – the specific heat, λ - the medium thermal conductivity, b – the depth of attenuation and ρ - the density of the rock.

Thus estimated temperature in the basin down to 4 km reaches about 160^0C and the total amount of heat beneath the basin estimated about 2.53×10^{15}J. That estimation shows the Hanoi basin is identified to intermediate enthalpy geothermal resource can be perspective place promising for going to prefeasibility step of exploration for electrical generation. The estimated potential of geothermal heat here

is about 1.6 percent in comparison to total electrical energy consumption in Vietnam in 2006 (Vu Manh Ha, 2007).

3.3 Aspects of ground source heat pump

The area of the Hanoi basin is hot in summer and warm in winter (HSWWZ), there are over 200 days in a year to demand air conditioning, mainly cooling in summer. An average temperature in year of the region is 23.4^{0}C. The area covers the territory of at least 8 provinces with about 16 millions of population. It is one of the two largest social – economic zones in Vietnam. There are many big cities, including the capital Hanoi as well as numerous industrial and crowded population centers in the study region, the demand of energy consumption is very big. In addition the electrical energy shortage is happened every year, especially in summer. The analysis of climate and ground temperature factors, underground water is indicated the reasonable solution is the use of the GSHP technology for saving energy in air conditioning in the area.

The mean maximal hot temperature in the area can reach the point of 26 to 37^{0}C around year, mean temperature of 27 to 29^{0}C is appeared during May to September and relative humidity is higher 80 percent are creating very hot feel climate and air conditioning is needed. The variation of the air temperature in Hanoi City is showed in the Fig. 6.

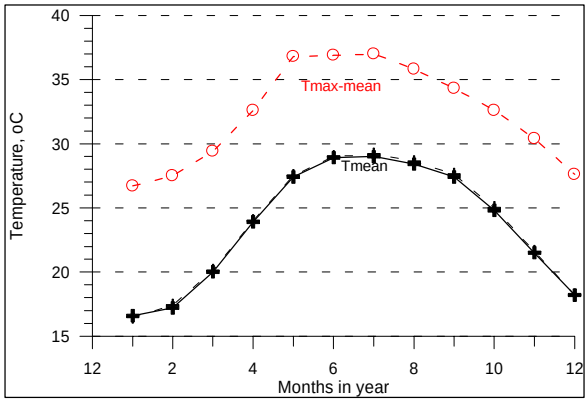

Figure 6: The observed mean air temperature in the year of Hanoi region during 1900 to 2005. $T_{max\text{-}mean}$ – Mean maximal temperature; T_{mean} – Mean temperature (Doan, et al., 2008).

In the hydrogeologic relation, Hanoi basin is composed by the unconsolidated Quaternary sediments with over 100 m thick, the underlying part are Neogen and other more consolidated rocks. There are two main aquifers in the Quaternary sediments, which are Pleistocene (q_p) and Holocene (q_h) distributed largely in the basin. They are main water sources for water supply in Hanoi basin. The natural dynamic reserves of the groundwater in the basin are estimated about 88.86 m^3/s (Bui Hoc et al.2005). The average thickness of the q_h aquifer is 13.6 m, ground water level is distributed at depths from 3 -5m to 10 m under surface. Its water potential with the transmission rate from 95 to 1788 m^2/day. The average thickness of the q_p aquifer is from some meter to hundreds meter distributed at depths from some tens meter to hundred meter from surface. Total of water abstraction in the aquifer in Hanoi city is about 1,000,000 m^3 per day.

The observed results of ground and groundwater temperature in shallow wells showed that the seasonal temperature variations affect to depths from 10 to 15 m from surface depending on the nearsurface soil. At the

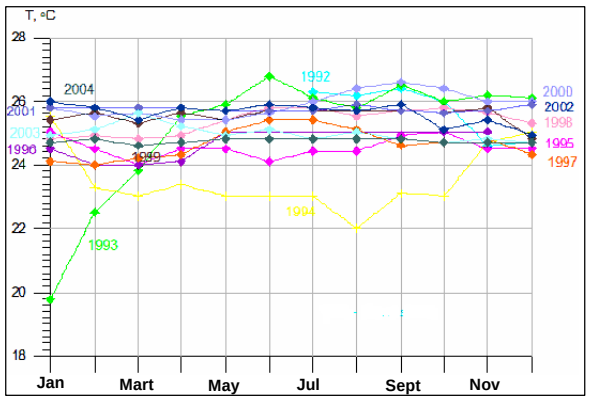

Figure 7: The typical mean groundwater temperature in the year of Hanoi region during 1993 - 2004 (Doan Van Tuyen et al., 2008).

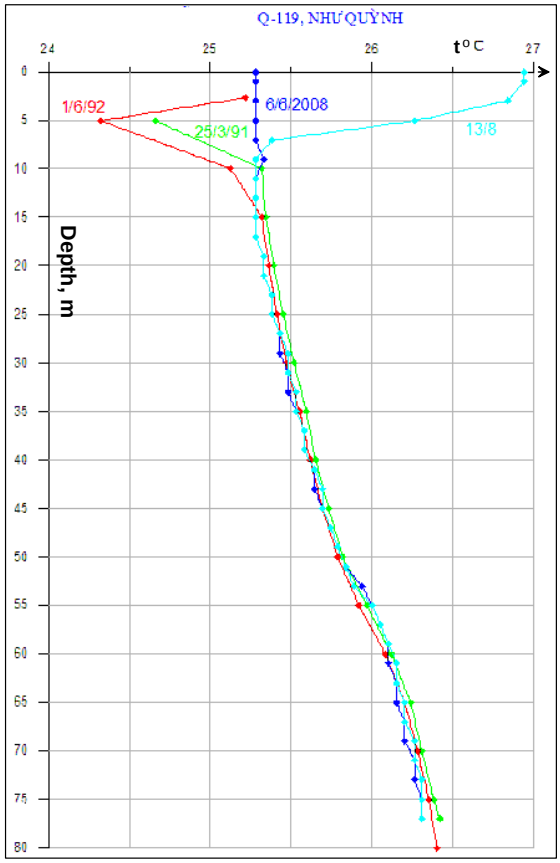

Figure 7: Typical deep –temperature dependence in Hanoi basin is observed during 1991 - 2008 (Doan Van Tuyen et al., 2008).

depths about 15 m the groundwater temperature around year is mostly a constant value. From 15 m deep to about 80 m the ground temperature is varied in very narrow range 25.3 -26.4^{0}C. In addition the temperature in Quaternary sediments is increased only at the rate 0.15 to 0.2^{0}C per 10 m. The typical variation of groundwater temperature in the region is shown in Fig. 7 and deep –temperature dependence is shown in Fig. 8.

In comparison with the maximal temperature in air from April to October during summer, the temperature in the ground water is always lower 7 - 10^{0}C. That factor allows us to consider the possibility to use the low-grade groundwater for saving energy with the conditioning purposes in the hot seasons.

4. CONCLUSIONS

Hanoi basin is one of the interested regions in Vietnam with favorability of geothermal potential:

Based on the results of different geological, geophysical and geothermal studies the initial data about resources and potential of geothermal energy in Hanoi basin is suggested. Thus the estimated temperature in the basin down to 4 km reaches about 160^0C and the total amount of heat beneath the basin estimated about 2.53×10^{15}J. In the southeastern part of the basin are detected the heat flow value greater 100 mW/m^2 and temperature 140^0C at depths 3000 m. This condition is capable of the prefeasibility investigations for the electrical power generation.

The hot water sources discovered widely in the Hanoi plain region is a valuable energy source for direct use in different economic and live utilization, such as aquaculture and agriculture, industrial uses, bath and medical treatment etc.

The long time duration of hot weather in summer demands very big power for air conditioning, that is the reason of the electric shortage permanently in summer. The initial results about geological, hydrogeological conditions as well as the soil and groundwater temperatures in the region show a good perspective for comprehensive use of the ground sources heat pump (GSPH) for air conditioning systems as a measure for saving of the energy consumption.

REFERENCES

Bui Hoc, Pham Khanh Huy. Groundwater management in Vietnam. J. of Geology. Series B. N.25, (2005), 24-30. Hanoi.

Cermk, V., and Rybach L.. Thermal conductivity and specific heat of minerals and rocks. In Physical properties of rocks, Vol. I-a, (1982), 305-403. Springer-Verlag.

Doan van Tuyen, Dinh Van Toan, Trinh Viet Bac. The study of geothermal resources to develop clean energy in Vietnam. Journal of science of the Earth, 30(2), (2008), 153-160, Hanoi.

Duchkov A.D., Nguyen Trong Yem, Dinh Van Toan, Trinh Viet Bac. First estimations of Heat flow in North Vietnam. J. Geology and Geophysics, Vol.33, N.5, (1992), 92-96. Novosibersk.

Mineral and thermal water sources of Vietnam, published by Department of Geology and minerals of Vietnam, 1998, 308p., Hanoi .

PetroVietnam. Procceding of National Congress on 30 year of PetroVietnam, Vol. I, (2007), p.239. Hanoi.

Schellschmidr R., Sanner B., Jung R. and Schulz R. Geothermal Energy Use in Germany. Proccedings European Geothermal Congress (2007), Unterhaching, Germany.

Steven H. Harder, Dinh Van Toan, Nguyen trong Yem, Trinh Viet Bac. Preliminary Heat flow Resunts from the Hanoi basin, Vietnam. In: Terrestrial Heat flow and geothermal energy in Asia. Ed. Gupta M.L. and Yamano M. Oxford & IBH publishing Co.,(1996), 163-172.

Tran Nghi, Chu Van Ngoi, Dinh Xuan Thanh. Evalution of Cenozoic sediments in Red River depression in relation with the tectonic activity . J. Science of the Earth, n. 4, (2000), 290-305, Hanoi .

Vu Manh Ha. Development of wind energy in Vietnam. Procceding of National symposium on marine energy in Vietnam – potential, technology and policy, (2007), 117-128. Hạ Long.