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Turkey's Municipal Solid Waste and Urban Waste Water Treatment Sludge Electrical Energy Potential

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Abstract. The role of indigenous and renewable energy resources is crucial for countries that want to be less dependent on foreign countries. Renewable energy resource power plants have many advantages when compared with other resources. They make countries less energy dependent and they also have environmentally friendly technologies when compared with other resources. Turkey is a country that has an abundance of renewable energy resources and biomass is one of the most promising energy resources in renewables.

The goal of this paper is to determine Turkey's electricity potential based on industrial wastes i.e. municipal solid waste (MSW) and urban wastewater treatment sludge potential, using applicable electricity generation methods. In this attempt, electrical energy potential of these resources has been found by using applicable waste to energy methods, technical and economical parameters.

Electrical energy potential of Biogas (Landfill gas included) based on these resources is an amount of 6.73 billion kWh/year. Municipal solid waste (MSW) and dried municipal wastewater treatment sludge electrical energy potential is an amount of 23.81 billion kWh/year.

Based on the resources stated; using the biogas and biomass energy values, calculations resulting in primary energy potentials; the installed capacity for gas-motor systems, gas-turbine systems (Simple cycle), gas & steam turbine systems (combined) and boiler – steam turbine systems have been determined.

Key words

Biomass, Biogas, Waste to energy, Municipal solid waste, Urban waste water sludge

1. Introduction

Wind, solar, aero thermal, geothermal, hydrothermal, ocean energy, hydroelectric, biomass, landfill gas, wastewater treatment plant gas and biogas are defined as non-fossil renewable energy resources [1].

Turkey's renewable energy support mechanism is based on feed-in tariff support mechanism to promote renewable energy resources. This mechanism has been regulated by "Law on Utilization of Renewable Energy Resources for the Purpose of Generating Electrical Energy". According to this law; power plants that have come into operation since 18 May 2005 or will come into operation before 31 December 2015 will be eligible to receive the following feed-in tariffs for the first ten years of their operation. Renewable energy resources in the scope of this Law are: wind, solar, geothermal, biomass, biogas from biomass (land fill gas included), wave, current and tidal energy resources together with hydraulic generation plants either canal or run of river type or with a reservoir area of less than fifteen square kilometres.

In addition, if the mechanical or electro-mechanical equipment of the power plant is produced locally, Premium tariffs shall be added to the feed-in tariffs during the first five years of operation [2].

Currently Turkey has no aero thermal, ocean energy, tidal and wave or solar energy systems that are connected to the main grid.

As of the end of June 2012; Turkey has 18,150.6 MW Hydroelectric, 114.2 MW geothermal, 132.9 MW bio-mass/waste, 2,013.2 Wind and 34,345.5 MW Thermal as installed capacity (Natural and LNG capacity is 16,389.3). According to these data, Turkey's totally installed power capacity is 54,756.5 MW. The share of natural gas power plants in Turkey's installed power capacity is around 30% [3]. Since data for hydroelectric sources which are supported as renewables could not be

found, all hydroelectric plants are accounted as renewables.

According to EMRA (Energy Market Regulatory Authority) data; Turkey has 33 licenced Biomass power production plants which have 165.856 MW licence capacity and 107.267 MW capacities in operation. 7 out of 33 plants are LFG power plants and 1 out of these power plants is urban waste water treatment sludge power plant. LFG power plants have 85.211 MW licence capacity and 56.719 MW capacities in operation whereas urban waste water treatment sludge power plant has 2. 436 MW licence capacity and 0 MW capacity in operation. This plant has been designed to use biogas that has been recovered through anaerobic digestion of the sludge and the plant managed by Konya Metropolitan Municipality [4].

Although there is no plant that uses incineration method to produce electricity from municipal solid waste or urban waste water treatment sludge, There are some biogas plants that produce electricity from waste through anaerobic digestion and an urban waste water treatment plant in the city of Konya that produce electricity through Anaerobic digestion. There are some cement plants that use dried waste water treatment sludge to produce heat energy by co-firing for their production.

Turkey's dependence on imported natural gas is 98% and Russia is the main supplier by supplying almost 52% of this gas according to the applied treaties. 51% of the imported gas is used for electricity production in Turkey [5].

Dependency on imported petroleum and coal is respectively; 90% and 20%. There is 10,000 MW lignite reserves [6] stay idle in Turkey. Turkey has a total installed potential capacity of 48,00 MW in wind, 600 MW in geothermal and 380 billion kWh/year in solar energy [7].

In the report prepared by European Commission in 1997, an increase of 8% in between 2010-2020 is seen fit, and by 2020 countries should receive at least 20% of their total energy needs from renewable resources [8]. According to Ministry of Energy and Natural resources 2010-2014 strategic plan, renewable resource capacity should be 30% of total installed capacity by 2023 [9]. All this data simply reflects Turkey's external energy dependency. To decrease Turkey's energy dependency on foreign supply, renewables and alternative energy resources have to be used with indigenous energy resources as well.

2. Methods of Electricity Generation from Biomass and Wastes

Biomass and disposed waste can be used in various different technologies to generate electricity. These technologies can be grouped into two; biological and thermochemical. Biological methods are: fermentation, anaerobic digestion, while the thermochemical technologies are incineration, gasification and pyrolysis. Worldwide speaking, today's World's waste to energy conversion is by 90%, by incineration.

Direct incineration is the most common source of energy conversion in waste. Many wastes to energy plants are using direct incineration method. In these plants, as steam temperature and pressure rise, efficiency increases [10].

Solid biomass and waste to heat and electricity generation is categorized into two: Incineration-based generation and Gasification based generation.

Incineration – based Generation: In the incineration process, the chemical energy in the fuel is converted into heat energy while being transferred into a heat exchanger. The fluid in the heat exchanger is dilated, creating mechanical energy.

Gasification – based Generation: In the gasification process, fuel is converted into usable gas by the addition of air or steam [11].

In this study; ındustrial wastes i.e. municipal solid waste and urban waste water treatment sludge potential and the electricity potential of these wastes' have been calculated.

3. Energy Potentials According to Resource Types

A. Municipal Solid Waste Energy Potential

The population where waste management is applied is 57,800,347 for the 3,129 municipalities of Turkey. Daily average waste amount per person is 1.15 kg/person-day [12]. For this average value, annual waste amount per person will be 0.42 ton /person per-year.

For the next 20 year period, the amount of land fill gas dependent upon the percentage of the methane within will be between 60-290 m^3/ton. This figures are valid for %50-60 organic matter in waste and the amount of methane that will be produced is %50 [13].

The amount of waste for the population where waste management is applied will be 24,276,145 ton/year. For the next 20 year period, the total waste amount will be 485,522,900 ton and produced land fill gas will be 48.55 billion m^3 for the assumption of 100 m^3/ton land fill gas production value [14]. The amount of gas that will be produced practically is equal to 40% of theoretically produced gas amount [14], with regard to this assumption produced land fill gas will be 19.42 billion m^3 for 20 years. This value will be 0.97 billion m^3 / year for the population where waste management is applied.

MSW biogas (Landfill gas-LFG) calorific value is; 19-23 MJ /m^3 (5.27 – 6.38 kWh / m^3) [15] and LFG with 50% methane has 17.20 MJ / m^3 (4.77 kWh / m^3) [16]. For 5 kWh/m^3 calorific value, MSW biogas energy potential is calculated to be 4.85 billion kWh.

Landfill sites and anaerobic digestion methods have been used in many plants to produce biogas from municipal solid waste. Incineration of municipal solid waste is also possible besides the other methods.

To produce electrical energy from solid wastes, calorific value of the waste must be between 2,000-2,500 kcal/kg [17].

According to the waste survey conducted by İstanbul Metropolitan Municipality Istanbul Environmental Management Industry Trade Co. (İSTAÇ A.Ş.) in 2009 winter season to characterize existing waste composition and calorific values; calorific value of the package wastes has been found to be between 2,167-3,750 kcal /kg. Mixed solids waste calorific value found to be between 1,160-1,669 kcal/kg.

The rate of paper, cardboard, plastic, textile, diaper and other combustible materials in this waste survey has been 41.10%. There is also combustible material in the organic part of the composition which is 54.09% of the composition [18].

Considering a well-developed and controlled waste management system for incineration, 16 metropolitan municipalities' population has been taken into account.

The population of 16 metropolitan municipalities of Turkey is 33,102,608. Daily average waste amount per person is 1.15 kg/person-day [12]. Annual waste amount is 13,903,095 ton/year. Because of the waste composition's calorific value, an assumption has been made and 40% of this waste has been considered for incineration. This amount is 5,561,238 ton/year. Mixed MSW average calorific value is 9.0 MJ / kg (9 GJ /ton) [19]. For this 9.0 GJ / ton (2,500 kWh / ton), the energy value is calculated as 13.90 billion kWh /year (13.90 TWh / year).

Table I. - MSW energy value

Population	33,102,608
Daily average waste amount (kg/person)	1.15
Annual waste amount (ton/year)	5,561,238
Mixed MSW average calorific value (GJ /ton)	9
Energy value (bn- kWh /year)	13.90

B. Urban Wastewater Treatment sludge Energy Potential

The gas produced in urban waste water pre-treatment plant is between 0.015-0.022 m^3/person per-day. In secondary treatment plant this value is about 0.028 m^3/person per-day. Calorific value of produced gas dependent upon the percentage of the methane within. For 65% methane rate the calorific value is 22.4 MJ/m^3 [20].

Considering the 33,102,608 people living in 16 metropolitan municipalities throughout Turkey, daily amount of gas will be about 827,565 m^3/day for 0.025 m^3/person per-day gas production value. The 16 metropoles will have 0.30 billion m^3/year annual gas amount. For 22.4 MJ/m^3 calorific value, the gas will approximately have 6.76 billion MJ (1.88 billion kWh) energy.

Table II. - Urban Wastewater Treatment sludge gas energy value

Population	33,102,608
Biogas yield (m^3 / person-day)	0.025
Annual biogas production (bn- m^3/ year)	0.30
Biogas calorific value (MJ / m^3)	22.4
Energy value (bn- kWh /year)	1.88

Drying of urban waste water treatment sludge and their incineration for recovering energy is possible.

In the wastewater treatment process, water and / or solid matter are pressed, leading to volume reduction. In the end of the process, the 90% dry matter is formed, which has a calorific value of 9-12 GJ / ton [21].

The dried sludge's calorific value is dependent upon the ingredient dry matter and the organic compounds within. If a 95% dry matter has 50% organic value, the calorific value is 11 GJ / ton [22].

Unprocessed sludge with 1 ton of dry matter will give out 4.2% of processed dried sludge after dewatering and thermal drying, which is at 95% dryness. In the wastewater treatment process, between 1-6% sludge can be recovered [23].

According to İSKİ (Water and Sewage Administration of İstanbul), the quota for household waste water is in between 130-180 Liters / person per day. This value is estimated to be in between 200-230 liters in 2040. More agreed upon value is 200 liters / person per day. According to this estimate, 70 to 80 percent of this household waste water is going to reach the sewers [24]. The density for wastewater treatment sludge is 1.0 kg/liter [25]. Considering the 33,102,608 people living in 16 metropolitan municipalities throughout Turkey [26], a calculation for dried waste water treatment sludge can be done. The calculations are presented in Table III. When the dried sludge processing is calculated; after the drying process, the amount of dried sludge gathered is 4.2% of the first total mass, which includes 95% dry matter. The 16 metropoles will have an annual dried sludge total of $3.427.10^9$ kg / year.

Table III. - Annual Dried sludge Values

Daily water usage (lt / person)	200
Annual water usage (lt / person)	73,000
Wastewater conversion ratio (%)	80
Annual wastewater usage (lt / person)	58,400
Sludge conversion ratio (%)	4.0
Annual sludge per person (lt / person)	2,336
Sludge density (kg / lt)	1.0
Annual sludge total (kg / person)	2,336
Dried sludge conversion ratio (%)	4.2
Annual sludge per person (kg / person)	98.112
Population for the 16 Metropoles	33,102,608
Dried sludge total for the 16 Metropoles (kg / year)	$3.247.10^9$

According to Table III, the dried sludge energy potential is calculated as 9.91 billion kWh / year for 11 GJ /ton (3,055.55 kWh / ton) calorific value. The biogas and dried biomass energy values are given in Table IV.

Table IV. - Biogas and Biomass energy Values

Source	MSW	U.W.Treatment Sludge	Tot.
Biogas Energy Value (bn-kWh/year)	4.85	1.88	6.73
Biomass Energy Value (bn-kWh/yıl)	13.90	9.91	23.81

4. Energy and Installed Capacity Values Responding to Applicable Electricity Generation Technologies

The efficiency and availability factors of machines and boilers are given. The efficiency for the gas motor is 40.4%, and its thermal efficiency is 42.9% [27]. The general conditions for the biogas production plants which use animal and plant wastes are; 8,000 annual work hours and 20-25 years of wear-down [28]. For 8,000 annual workable hours the availability rate will be 91%. The calculations based on applicable electricity generation technologies have been made with the assumption of 8,000 working hours.

Gas turbine's electrical efficiency is 30% and its thermal efficiency is 68% [29]. The thermal efficiency for the horizontal water piped waste heat boiler (H-WTB) is 90% [30]. Steam turbine's electrical efficiency is 44% [29]. MSW boiler's efficiency is 69.9% [31].

A. Gas Motor system Calculations

According to the energy values given in Table IV, values for gas motors are stated in Table V.

Table V. - Gas Motor system Values

Source	MSW	U.W.Treatment Sludge	Tot.
Biogas Values (bn-kWh/year)	4.85	1.88	6.73
Gas Motor Electrical Efficiency (%)	40.4		
Secondary Enery Values (bn-kWh/year)	1.96	0.76	2.72
Availability (%)	91		
Installed Capacity (GW)	0.24	0.09	0.33

B. Gas Turbine Calculations

According to the energy values given in Table IV, values for gas turbines are stated Table VI.

Table VI. - Gas Turbine system Values

Source	MSW	U.W.Treatment Sludge	Tot.
Biogas Energy Values (bn-kWh/year)	4.85	1.88	6.73
Gas Turbine Electrical Efficiency (%)	30		
Secondary Energy Values (bn-kWh/year)	1.46	0.56	2.02
Availability (%)	91		
Installed Capacity (GW)	0.18	0.07	0.25

C. Gas Motor – Steam Turbine Systems (Combined)

According to the installed capacity values (GW) given in Table V Gas motor exhaust outputs are used again for electricity generation. The values for the system are stated in Table VII.

Table VII. - Gas Motor-Steam Turbine system Values

Source	MSW	U.W.Treatment Sludge	Tot.
GM (GW)	0.24	0.09	0.33
Gas motor thermal efficiency(%)	42.9		
Exhaust boiler thermal efficiency (%)	90		
Steam turbine electricity efficiency (%)	44		
Net Efficiency (%)	16.9		
BT output Power for GM (GW)	0.040	0.015	0.055
Total Combined Power (GW)	0.280	0.105	0.385

With an addition of a heat boiler and steam turbine, a 16.6% increase is observed in gas motors.

D. Gas – Steam Turbine Systems (combined cycle)

According to the installed capacity values (GW) given in Table VI Gas turbine exhaust outputs are used again for electricity generation. The values for the system are stated in Table VIII.

Table VIII. - Gas – Steam turbine system values

Source	MSW	U.W.Treatment Sludge	Tot.
GM (GW)	0.18	0.07	0.25
Gas Turbine Thermal Efficiency (%)	68		
Exhaust boiler thermal efficiency (%)	90		
Steam turbine electricity efficiency (%)	44		
Net Efficiency (%)	26.9		
BT output Power for GT (GW)	0.048	0.018	0.066
Total Combined Power (GW)	0.228	0.088	0.316

With an addition of a heat boiler and steam turbine, a 26.4% increase is observed in gas turbines.

E. Boiler – Steam turbine systems

According to the energy values given in Table IV, values for the system stated in Table IX.

Table IX. - Biomass incineration values

Source	MSW	U.W.Treatment Sludge	Tot.
Biomass Energy Values (bn-kWh/year)	13.90	9.91	23.81
Boiler Thermal Efficiency (%)	69.9		
Steam Turbine Electrical Efficiency (%)	44		
Net Efficiency (%)	30		
Secondary Energy Values (bn-kWh/year)	4.17	2.97	7.14
Availability(%)	91		
Installed Capacity (GW)	0.521	0.372	0.893

Incineration of biomass results in 0.893 GW, which shows that these resources have high calorific value, that could also be used for regional heating purposes.

5. Conclusions

Other methods of electricity generation that differ from MSW- gas - gas motor are described in this article. Incineration method and other electricity generation technologies have been used to define electrical energy potentials.

Turkey's indigenous fossil fuel energy resources are not rich in deposit, so effective usage is of critical importance. Renewable strategies will lessen the impact of foreign dependence on resources (natural gas etc.), thus having a positive effect on Turkey's economy.

Utilizing waste to energy system is also beneficial since it helps destroy wastes. This paper in general will help our country to more effectively use its biomass resources.

Throughout Turkey, biogas potential through MSW is 0.97 billion m3/year and urban wastewater treatment sludge has a biogas potential of 0.30 billion m3/year for Turkey's 16 metropolitan municipalities.

Throughout Turkey, biogas energy potential through MSW is 4.85 billion kWh/year and urban wastewater treatment sludge has a potential of 1.88 billion kWh/year for Turkey's 16 metropolitan municipalities. These figures sum up to an amount of 6.73 billion kWh/year.

Total energy values for MSW and dried urban wastewater treatment sludge are respectively: 13.90 and 9.91 billion kWh/year for Turkey's 16 metropolitan municipalities. These figures sum up to an amount of 23.81 billion kWh/year.

Installed capacity for gas motors, gas-turbine systems, gas-motor steam-turbine systems (combined), gas-turbine steam-turbine (combined) and boiler-steam turbine systems are respectively; 0.33 GW, 0.25 GW, 0.38 GW, 0.31 GW, 0.89 GW.

With an addition of waste heat boiler and a steam turbine to the gas motor, it is observed that the waste heat can grant a %16.6 increase in energy. The addition of the same equipment to a gas turbine instead, presents itself with a rise of 26.4% in energy.

As of late June 2012, Turkey's biomass / Waste power plants total capacity was 132.9 MW and this rate is 0.24 percent of the total installed capacity of Turkey. In comparison with the present biomass / waste installed capacity, installed capacity values that have been found in this study show big resources that have to be evaluated.

Biomass energy generates far less air emissions than fossil fuels, reduces the amount of waste sent to land and decreases the countries' reliance on foreign countries. This resource is clean and sustainable as well.

High cost of investment and operations, requirement of highly skilled personnel, risk of residues from the flue gas, a well-developed and controlled waste management system and correct handling of ash and slag are important factors in incineration. Landfill and Waste incineration methods should be correctly compared to one another and the relevant waste management procedures should be carefully decided upon.

References

[1] Directive 2009/28/EC of the european parliament and of the council 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, Official Journal of the European Union, L 140/61, 5.6.2009

[2] Law on making amendment in the law related to using of renewable energy sources for purpose of generating electric energy, Official Gazette , 2011;2789

[3] Yük tevzi Daire Başkanlığı İşletme Faaliyetleri Raporları, TEİAŞ, http://www.teias.gov.tr/yukdagitim/kuruluguc.xls (Accessed: 9 Agust 2012)

[4] Electric Market Licence datas, Energy Market Regulatory Authority (EMRA), http://www2.epdk.org.tr/lisans/elektrik/lisansdatabase/verilentesistipi.asp, (Accessed: 9 August 2012)

[5] The Turkish natural gas market-expectations and developments 2012, Deloitte, Ankara, (2012)

[6] Introducing of lignite coal fields to economy, Deloitte, Ankara, (2012)

[7] The Turkey energy report 2009, The world Energy Council – Turkish National Committee, Ankara, (2009)

[8] European Renewable Energy Council, "Renewable Energy Targets for Europe", EREC, Brussels,(2004).

[9] Ministry of Energy and Natural Sources , "Ministry of Energy and Natural Sources 2010-2014Strategic Plan", http://www.enerji.gov.tr/yayinlar_raporlar/ETKB_2010_2014_Stratejik_Plani.pdf, (Accessed: 12 December 2010),

[10] Tezçakar, M., Can, O., " Thermal Disposal Technologies in obtaining energy from wastes ", 2. Waste Technologies Symposium and Exhibition, İstanbul, 04-05 November,(2010),

[11] Spliethoff, H., "Power generation from Solid Fuels",Berlin,(2011).

[12]T.R. Prime Ministry Turkish Statistical Institution , Municipality Waste Statistics - 2008, TurkStat News Bulletin, Number:50, TurkStat, Ankara,(2010),

[13] Sezgin N., Özcan H.K., Varınca K., Borat M., "Katı atık depo gazından elektrik üretiminin Türkiye'de uygulanabilirliğine iki örnek: İstanbul ve Bursa tesisleri", www.yildiz.edu.tr/~kvarinca/Dosyalar/Yayinlar/yayin001.pdf, (Accessed: 18 November 2010),

[14] Erdin E., "Çöplüklerden (Deponilerden) Enerji Elde Edilmesi", http://web.deu.edu.tr/erdin/pubs /doc116.htm, (Accessed:18 November 2010),

[15] Digest of United Kingdom Energy Statistics 2010, http://www.decc.gov.uk/assets/decc/statistics/publications/dukes/348-dukes-2010-printed.pdf, (Accessed: 3 November 201)

[16] Veneziani, L., "Landfill gas: turning a problem into a valuable Resource", 3. Waste Technologies Symposium and Exhibition 02-03 November, İstanbul,(2011).

[17] Öztürk, İ., Demir, İ., Özabalı, A., Tezer, B.H., "Strategic plan of the integrated solid waste management in consistent with the EU environmental legislation for İstanbul", İstanbul Metropolitan Municipality, İstanbul,(2005).

[18] Saltabaş, F., Soysal, Y., Yıldız, Ş., Balahorli, V., "Municipal solid waste thermal disposal methods and its applicability in İstanbul, Sigma Journal of Engineering and Natural Sciences, Number:3, pp:109-116, (2011).

[19] Integrated Pollution Prevention and Control Reference Document on the Best Available Techniques for Waste Incineration , August 2006, European Commission

[20] Filibeli A., Büyükkamacı N., Ayol A., "Aneorobik arıtma", İzmir,(2000).

[21] Verschueren, I., "Strategy and practical experience of sewage sludge management in Flanders Belgium", IWES-3. Waste Technologies Symposium and Exhibition, 02-03 November 2011, WOW Convention Center, İstanbul, TURKEY.

[22] İnan, A., "Drying of sewage sludge with waste heat to obtain alternative fuel", IWES-3. Waste Technologies Symposium and Exhibition, 02-03 November 2011, WOW Convention Center, İstanbul, TURKEY.

[23] "Çamur arıtımı ve uzaklaştırılması", http://web.deu.edu.tr/atiksu/ana58/bolum08.pdf, (Accessed: 16 December 2011).

[24] Erdoğan, A.O., Zengin, G.E., Orhon, D., "Domestic wastewater formation amounts in Turkey and their characterization", itü magazine/e water pollution control, volume:15, number:1-3, 57-69, (2005).

[25] Filibeli A. "Arıtma Çamurlarının Genel Özellikleri", Çevre Ve Orman Bakanlığı Çevre Görevlisi Ve Çevre Görevlisi Eğiticisi Eğitim Programı notları, Ankara,(2009),

[26] T.R. Prime Ministry Turkish Statistical Institution, The Results of Address Based Population Registration System-2011, http://tuikapp.tuik.gov.tr/adnksdagitapp/adnks.zul, (Accessed: 16 December2011).

[27] GE Jenbacher GmBh&Co OHG, "JMS 312 GS-BL/ Biogas 526 kW el. Technical specification", http://www.cogeneration.com.ua/img/zstored/J312V221_en.pdf ,(Accessed: 09 December 2011),

[28] Kaya D., "Assessment of using of domestic source sewage sludge in biogas generation ", "ICCI – International Energy and Environment Exhibition and Conference" İstanbul, 12–14 May,(2010),

[29] Horlock, J.H., "Cogeneration-Combined Heat and Power (CHP)-Thermodynamics and Economics", Krieger Publishing Company, Florida, (1997).

[30] Çolak,M., Tüzer,B., "31.5 MW CHP Natural Gas power plant operation datas", Şişecam Camiş Electric Generation Company Thrace Regional Power Plant, Kırklareli, (2012)

[31] Elliott, T.C., Chen, K., Swanekamp, R.C., "Standard Handbook of Powerplant Engineering-2nd edition", McGraw-Hill, (1998).