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Modelling of Government Support in Biopower Plant

Projects: The Case of Thailand

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Abstract

Over the past decade, several policies have been developed and implemented to support the investment in renewable energy (RE) projects around the world. One of the most popular support programs is Feed-in Tariff or FIT. In Thailand, a type of FITs called “adder program” is employed to pay additionally RE producers for the amount of electricity generated from RE sources, at a fixed rate as specified in power purchase agreement (PPA), regardless of the actual operating costs of the RE projects. For biopower plants, it is commonly known that biomass price fluctuation is the most important risk of the projects. This paper examines the efficiency of current subsidy policies used in Thailand in supporting the development of biopower plant projects. We then propose two new mechanisms of governmental support: biomass price guarantee (BPG) and minimum income guarantee (MIG). We compare the expected costs of subsidy under each subsidy program, assuming that the biomass prices follow a stochastic process called Ornstein-Uhlenbeck. The results of risk analysis using Monte Carlo simulation show that the most cost-effective mechanism is the BPG.

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1. Introduction

The most important, primary sources of energy in the world are fossil fuels, such as coal, oil, and gas, because of their ability to produce the highest amounts of energy per unit weight. However, they are limited, and, at the current using rate, they cannot provide us the energy indefinitely. This is the main reason why alternative energy, particularly from renewable energy sources, can help supply the world's demand for energy. Renewable energy (RE) such as sunlight, wind, and biomass is more sustainable and environmental friendly than fossil fuels. However, because most RE projects face higher capital and technology costs [1], they cannot financially compete with conventional energy projects. This leads to less interest of private sectors in investing in RE projects if government support to reduce the risk is not adequate.

Despite the above-mentioned issue of RE investment, governments around the world still want to encourage more private investors' involvement in RE generators. In particular, they have become more interested in RE projects for two main reasons. First, they want to be energy-independent by decreasing the amount of imported oil and natural gas used to produce electricity. If this goal was achieved, it could improve the security of power supply. Second, power plants that use renewable sources (RS) have less impact on the environment than that of conventional fossil fuels.

However, increasing private investment in renewable energy projects is not an easy task. This is because the key driver of most private investment is profit. Without sufficient profits, private investor will seek other types of projects that provide high yields for the same risk level of investment. This is the primary reason why private investors around the world are still reluctant to invest in RE projects. Besides higher cost of capital, some renewable energy projects such as biopower plants usually face much higher input price uncertainty and supply availability than those of conventional fossil fuels.

One of the program adopted by the Thai government in promoting more investments in RE projects is through a support program called adder program, which is basically the subsidy money paid to electricity generators for the amount of their produced electricity. According to power purchase agreement (PPA), which is a contract specifying the amount of electricity to be produced and the selling prices, electricity generators will receive a known stream of cash flow revenue plus subsidy money received from the government.

The Thai government has recently revealed its ambitious plan to achieve the energy security goal within the next 15 years, according to a report named 15-Year Renewable Energy Development Plan [2]. The report laid out a plan to increase the share of renewable energy to about 20% of total energy consumption. Sources of renewable energy being considered to harness from include wind, solar, and biomass. Accordingly, this will inarguably increase the challenge in promoting renewable energy investment in Thailand.

In case of power plants that use biomass as feedstock (i.e., biopower plants), the financial outlook is not so attractive to many investors. The primary concerned factors to the investors are the availability and the price fluctuation of biomass, making the costs of producing electricity difficult to predict. Although, the government already provides a subsidy through the adder program, the subsidy simply provides the fixed amount of support, which sometimes is inadequate during the period of high production costs. Meanwhile, during the low costs of production, government subsidy is considered to be a waste to tax payers, that is, the government is over-subsidizing the investors for such the period.

Essentially, the paying mechanism of the adder program does not match the actual risk profile of biopower plant projects, which tends to evolve *randomly* or *stochastically* according to the underlying risks, e.g., biomass prices. In fact, according to the concept of risk management, risks should be transferred to the party that can best manage them at the lowest possible costs. Risks that cannot be managed by both parties (e.g., commodity prices) should be shared fairly through a contract.

Accordingly, this paper proposes two alternative mechanisms for risk management in biopower plants that takes into account the fundamental concepts of risk management. We primarily focus the study on the biomass price as it is the key underlying risk of biopower plant projects. Stochastic modelling is employed to represent the random movement of biomass prices. Once this modelling is completed, we then present two new mechanisms, biomass prices guarantees (BPG) and minimum income guarantees (MIG), as the alternatives to the adder program used by the Thai government. To illustrate how the proposed model and framework can be applied in real practice, we use numerical example of a hypothetical biopower plant project for the purpose of demonstration. The results are then discussed and the implications of findings will be provided.

2. Renewable support policies

According to Renewable Energy Policy Network for the 21st Century (REN21) Global Status Report 2012 [3], the global renewable energy support can be classified into three types: regulatory policies, fiscal incentives, and public financing (as shown in Fig.1). Regulatory policies are rules that guide or control the conduct of those to whom it applies. In the renewable energy context, examples include mandates or quotas such as renewable portfolio standards, feed-in tariffs, biofuel blending mandates, and renewable heat obligations. Fiscal incentives are economic incentives that provide actors (individuals, households, companies) with a reduction in their contribution to the public treasury through income or other taxes, or with direct payments from the public treasury in the form of rebates or grants. Finally, public financing is an approach under which public authorities organize financing such as loan, grant or bidding for support in renewable energy projects.

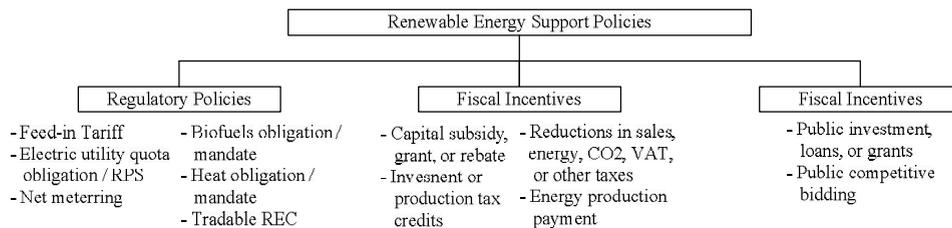


Fig. 1. Schematic renewable energy support policies (Source: [3])

In the report, it found Feed-in Tariffs (FITs) are now being used in 87 countries around the world, compared with 46 countries in 2006. This is due to the mechanism of FITs can reduce financial risks for RE projects [4]. The country that successfully promotes the investment in renewable energy projects through FIT is Germany, who had increased the power generation from RE sources to over 20 terawatt-hour between 1998 and 2002 [5].

Currently, there are two policies adopted by the Thai government: (1) feed-in tariffs (FITs) and (2) public investment, loans, or grants. However, in this paper we focus on only the former type of policies.

In Thailand, the government is supporting biopower plants through the adder program, which is characterized as the “fixed-price FIT payment” [6]. Under this policy, the government will pay additional amount of money according to the unit or kilowatt-hour (kWh) of electricity produced, and the total FIT payment to the project is independent of the electricity price. From fixed-price FIT policies, this provides certain amount of subsidy conditions for investors as shown in Fig. 2. Accordingly, this risk reduction helps lower project financing costs [7].

3. Economic analysis of biopower plant projects

Economic analysis of a project is considered to be one the very first step of project feasibility studies. Economic analysis tools such as the net present value (NPV) and internal rate of return (IRR) are commonly used to determine the financial viability of a project. The net present value is basically defined as the net sum of present values (PVs) of the individual cash flow of the same time period (t), as depicted in Fig.2.

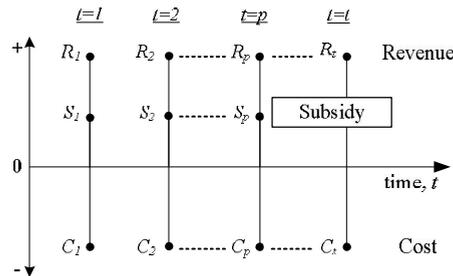


Fig. 2. Cash flow diagram of a biopower plant project

The NPV can be calculated by the following equation:

$$NPV(i, N) = \sum_{t=0}^N \frac{I_t}{(1+i)^t}, \quad (1)$$

where: I_t : the net cash flow at the end of year t .
 N : the number of project years.
 i : discount rate.
 t : project period (year).

The net income of the biomass power plant can be computed from cash flow stream shown in Fig. 2, which can be represented as follows.

$$NPV(i, N) = \sum_{t=0}^N \frac{R_t + S_t - C_t}{(1+i)^t}, \quad (2)$$

where R_t : revenue in year t .
 S_t : subsidy received in year t .
 C_t : total cost in year t .
 i : the discount rate, computed using weighted average cost of capital (WACC):

$$WACC = \left(\frac{D}{D+E} \right) (1-Tax) K_D + \left(\frac{E}{D+E} \right) K_E,$$

where D, E, K_D, K_E , and Tax is the total debt, total equity, the cost of debt, the cost of equity, and tax rate (e.g., 30%), respectively.

Eq. (1) can be represented by substitution with revenue (R_t), cost function (C_t), and debt service (D_t) into the previous equation, and we then have the equity cash flow (ECF) of the project as follows.

$$ECF_t = O \times P_t + S_t - M_t - OM_t - D_t, \quad (3)$$

$$NPV(ECF) = \sum_{t=0}^N \frac{O \times P_t + S_t - M_t - OM_t - D_t}{(1+i)^t}, \quad (4)$$

where O is the amount of unit electricity output. P_t is the electricity price; and, M_t , OM_t and D_t is the material, operating & maintenance cost, and debt service cost, all relative to year t .

4. Deterministic economics analysis

4.1. Case example project: A 500 kWh biopower plant

In order to illustrate the economic analysis of a case example biopower plant project (a 500 kWh biopower plant), key parameters are assumed to have the values according to the details presented in Table 1.

Table 1. Keys parameter of a example project

Parameters	Value	Parameters	Value
O	\$2,340,000 unit/year	OM_t	\$2,916 per year
P_t	\$0.097 per unit	D_t	\$345,076 per month
M_t	\$127,806 per year	K_E	Cost of equity = 15%

4.2 Results of deterministic economic analysis

Once all parameters of the case example project are determined, we can compute the net income received by the equity investors, which is called equity cash flow or ECF. The net present value of project's ECF is computed by Eq. (3). The results are presented in Table 2.

From Table 2, it can be seen that the adder program help improve the NPV of the project from \$89,945 to \$220,090. However, it costs the government about \$130,150.

Table 2. Result of project's NPV analysis

Mechanism	Project NPV (\$US)	Cost of government subsidy (\$US)
No support	89,945	-
Adder program	220,090	130,150

5. Stochastic biomass price model

Stochastic process is defined as a set of random variables, which can be represented as $\mathbf{X} = \{X_n : n \geq 0\}$ or $\mathbf{X} = \{X_n\}$, where X_n is state of the random process at time n , and its initial state is X_0 . Brownian motion (also called a Wiener process) is one of the most important basic notions of stochastic processes. Brownian motion originally refers to the random motion observed under microscope of pollen immersed in water. It is also a continuous-time Markov stochastic process whose increments are independent, no matter how small the time interval. Specifically, if $z(t)$ is a Brownian motion, then any small change in z , dz , corresponding to a very small time change dt , satisfies the following conditions:

- i. The relationship between dz and dt is given by $dz = \varepsilon_t \sqrt{dt}$, where ε_t is a normal distributed random variable with a mean of zero and a standard deviation of one.
- ii. ε_t is serially uncorrelated, that is, $E(\varepsilon_t \varepsilon_s) = 0$ for $t \neq s$.

Note that standard Brownian motion has a drift rate of zero and a unit variance. The generalized Wiener process can be presented by the following Eq. (5)

$$dx = a(x,t)dt + b(x,t)dz \quad (5)$$

A special case of Eq. (5) is the geometric Brownian motion with drift, where $a(x,t) = \alpha x$ and $b(x,t) = \sigma x$, with α and σ being constant. In this case the process $x(t)$ becomes

$$dx = \alpha x dt + \sigma x dz \quad (6)$$

More detailed treatment of stochastic process can be found in [8] and [9].

5.1 Choices of Stochastic Processes for Modelling Biomass Prices

It is usually assumed that commodity prices follow geometric Brownian motion (GBM) where the logarithm of the underlying variable follows generalized Wiener process. The price of a non-dividend paying commodity, P , following geometric Brownian motion, is mathematically represented by

$$\frac{dP}{P} = \mu dt + \sigma dz, \quad (7)$$

where μ is the expected return of the commodity, dz is a Wiener process, and σ is the volatility of the commodity price, and dP/P can be think of as the rate of price change.

Examples of researchers whose work uses stochastic processes to model the commodity price behavior are Schwartz [10] and Pelet [11]. For instance, Pelet [11] developed a stochastic model to forecast the oil price. Another one example, Clancy et al. [12] used a stochastic model to describe the fluctuation of biomass prices, which can mathematically be represented by the following equation

$$M_t = \alpha + \delta t + \varepsilon_t, \quad (8)$$

where: M_t : the price of biomass at time t
 α : the price of biomass at present time
 δ : the trend of biomass price
 ε_t : the random part following normal distribution with a mean of zero and a variance of σ_ε^2 , i.e., $\varepsilon_t \sim N(0, \sigma_\varepsilon^2)$

However, his model did not take into account the fluctuation of the biomass prices, which could lead to an error in predicting the future biomass prices.

5.2 Modelling of Biomass Prices Fluctuation

In practice, GBM in its standard form does not well represent the price fluctuation of commodity. Therefore, we may modify the GBM process to contain some essential effects such as *mean reversion* and

seasonality for achieving more realistic representations of price evolutions in natural gas and electricity markets.

In this paper, we assume that commodity prices on average move toward a long-term mean, then the evolution of commodity prices can be represented by the Ornstein-Uhlenbeck model:

$$dM_t = \kappa(L - M_t)dt + \sigma dz, \quad (9)$$

where M_t is the price of biomass at time t , L is the long-term mean of commodity prices, and κ is the speed of mean reversion. The first term on the right side represents a deterministic drift of prices. It will drift up when prices are below the long-term mean M and vice versa.

5.3 Simulation of Future Biomass Prices

Using the Ornstein-Uhlenbeck model given in the previous section, we simulated 5 biomass price paths (M_t) (as shown in Fig. 3) to illustrate how the prices of biomass will evolve in the future.

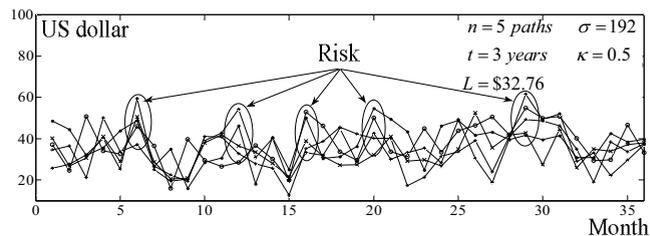


Fig. 3. Modelling of biomass prices using mean reversion model

6. Renewable energy support mechanisms

6.1. Current support mechanism (Adder Program)

Owing to the amount of subsidy by the current Thai mechanism support model or adder program is a function of capacity electricity. In case of Thailand, both of two factors are fixed by PPA contract. Therefore, the biopower plant receives the constant subsidy following the first specific capacity electricity in PPA contract as shows in Fig. 4.

The annual subsidy received through adder program is a function of the subsidy rate, which fixed at 0.01 dollar/kilowatt-hours, and the amount of electricity produced, which can be presented as the following equation.

$$S_{(FIT)_t} = R \cdot (Q \cdot Hr \cdot D \cdot 12) \quad (10)$$

where $S_{(FIT)_t}$: subsidy received in year t time,
 R : rate of subsidy (dollar),
 Q : capacity (watt),
 Hr : operating hours in each day (hours),
 D : operating days in each month (days).

The total net present value (NPV) of the subsidy is then calculated by the following equation

$$NPV(S_{FIT}) = \sum_{i=1}^{i=p} \frac{FIT_t}{(1+i)^t}, \quad (11)$$

where $NPV(S_{FIT})$: the NPV of subsidy under the FIT mechanism
 i : the discount rate factor
 p : the number of subsidy years

6.2. Modelling of support mechanisms

In this section we propose two new mechanisms in order to comparison and find the effective mechanism that is in line with the high benefit by the low subsidy.

6.2.1 Biomass Price Guarantee (BPG) Model

In generally, the projects will face significant risks of high costs of materials. In fact, agricultural material prices always fluctuate which may be the result of the season, output quantity, natural disaster, etc. One possible solution to biomass price fluctuation is to use a mechanism called biomass price guarantee (BPG).

In the BPG, the government will compensate the biopower producers if the biomass prices are above the guarantee price of K_{BPG} . The amount of money paid (i.e., subsidy money) to the biopower producers is the difference between the actual biomass prices and the guarantee price, that is, subsidy = $\max(P_t - K_{BPG}, 0)$. Graphical representation of this mechanism is shown in Fig. 5.

Therefore, the amount of subsidy and total present value of subsidy can be computed by Eq. (12) and Eq. (13), respectively.

$$S_{BPG,t} = \max(0, P_t - K_{BPG}), \quad (12)$$

where $S_{BPG,t}$: BPG subsidy in year t time
 K_{BPG} : guaranteed level
 P_t : biomass price in year t time

The net present value of the subsidy is computed as

$$NPV(S_{BPG}) = \sum_{i=1}^{i=p} \frac{S_{BPG,t}}{(1+i)^t}, \quad (13)$$

where $NPV(S_{BPG})$: the NPV of subsidy under the BPG mechanism
 i : the discount rate factor
 p : the number of subsidy years

6.2.2 Minimum Income Guarantee (MIG) Model

The minimum income guarantee (MIG) is usually used in infrastructure projects such as toll roads [13], [14], [15], and [16]. In this paper, we introduce the use of the MIG in RE projects, and the mechanism of MIG can be depicted as shown in Fig. 6.

The guaranteed income level can be established to reflect the actual risk profile of the project or at least equal to the risk-free rate such as government bonds (currently about 5% per year). Under this type of guarantee, if the periodic (e.g., annual) income fall below the guaranteed level, government will compensate for the shortfall. The received subsidy can be then computed by Eq. (14).

$$S_t = \max(0, K_{MIG} - I_t), \tag{14}$$

- where S_t : subsidy received from government in year t time
- K_{MIG} : guarantee threshold relative to year t
- I_t : income in year t time

In order to comparing with current support mechanism, the total amount of subsidy in present value can be calculated using Eq. (13).

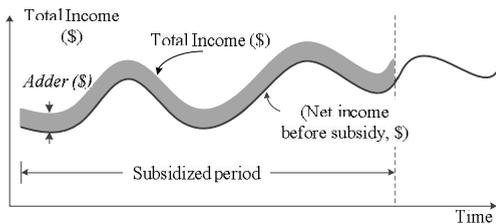


Fig. 4. Adder program support model

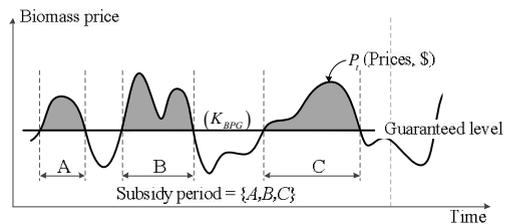


Fig. 5. Biomass price guarantee (BPG) model

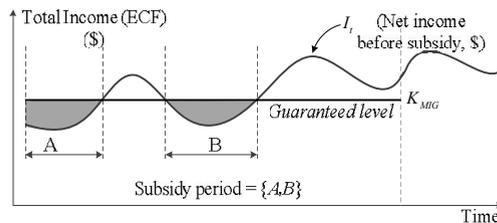


Fig. 6. Minimum income guarantee (MIG) model

6.3 Results of Probabilistic Economic Analysis

In the previous section, we already discussed how the deterministic economic analysis works. In this section, the NPV of the example case project will be calculated using a probabilistic approach.

The random variable under this study is the biomass price, which is assumed to follow a mean-reversion model. We use Monte Carlo method to simulate the possible values of biomass prices and then compute the net present value of the case project, accordingly.

The results of the simulation (with the number of simulation of 20,000) for each governmental support model are presented in Fig. 7 and summarized in Table 3.

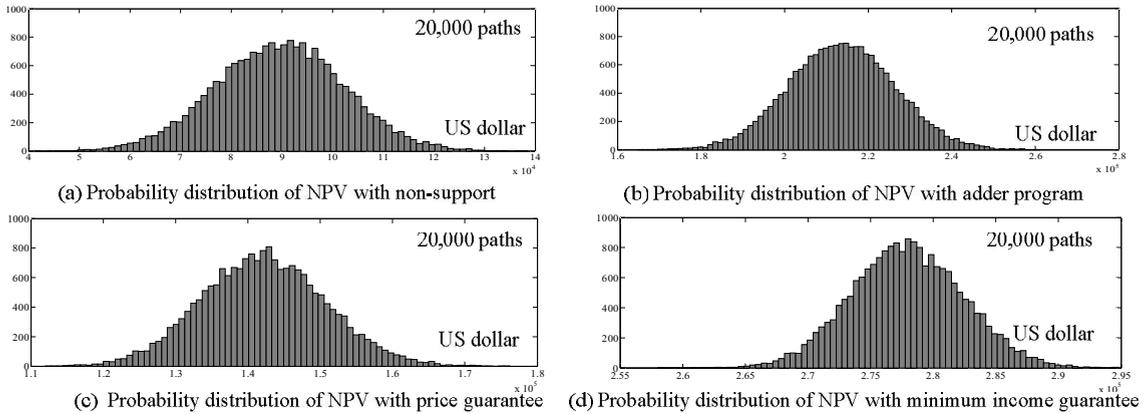


Fig. 7. Histogram of project’s NPV for each government support scheme

Table 3. Expected project’s NPV and costs of subsidy

Government support mechanism	Expected NPV of project (US dollar)	Expected government support (US dollar)	Economic efficiency of policy
No support	89,597	-	-
Adder program	219,740	130,150	1.69
BPG	143,920	48,926	2.94
MIG	277,800	188,120	1.48

7. Discussion and conclusion

As shown in Table 3, each government support mechanism results in different NPV of the project. However, in terms of the efficiency of the designed subsidy policy, this study finds that the most cost-effective policy is the BPG, with the economic efficiency of about 2.94, the highest among government support mechanisms under this study. Compared with the current government support or the adder program, the BPG pays significantly less subsidy (about \$48,926) while the project NPV of the project increases to \$143,920. Accordingly, based on the result of this study, we encourage government adoption of the BPG as a new government support for biopower plant projects.

References

- [1] Boomsma, T. K., Meade, N., & Fleten, S.-E.; *Renewable energy investments under different support schemes: A real options approach*. European Journal of Operational Research 2012; 220(1): 225-37.
- [2] Thailand’s Ministry of Energy; *Renewable Energy Development Plan: REDP*. Available at <http://www.eppo.go.th/ccep/energy_3-5.html>
- [3] REN21; *Renewables Global Status Report (GSR)*. Available at <http://www.ren21.net/Portals/0/documents/Resources/GSR_2012_low%20res_FINAL.pdf>
- [4] Mitchell, C., Connor, P.; *Renewable energy policy in the UK 1990–2003*. Energy Policy 2012; 32: 1935–47.
- [5] Mitchell, C., Baucknecht, D., Connor, P.M.; *Effectiveness through risk reduction: a comparison of the renewable obligation in England and Wales and the feed-in system in Germany*. Energy Policy 2006; 34: 297–305.
- [6] Cory, Karlynn et al. 2009. *Feed-In Tariff Policy: Design, Implementation, and RPS Policy Interactions*. National Renewable Energy Laboratory’s Technical Report, NREL/TP-6A2-45549; 2009.
- [7] de Jager, D.; Rathmann, M.; *Policy instrument design to reduce financing costs in renewable energy technology projects*. ECOFYS, Commissioned by the International Energy Agency – Renewable Energy Technology Deployment, Utrecht; 2008.
- [8] Vose, D. *Risk Analysis: A Quantitative Guide*: Wiley; 2008.
- [9] Dixit, R. K., Pindyck, R. S. *Investment under Uncertainty*: Princeton University Press; 2012.

- [10] Schwartz, S.; *The Stochastic Behavior of Commodity Prices: Implication for Valuation and Hedging*. Journal of finance 2006; 52(3): 923-73.
- [11] Pelet M.; *Real Options in Petroleum: Geometric Brownian Motion and Mean-Reversion with Jumps*. M.Sc. Thesis, Department of Mathematical Modelling and Scientific Computing, New Oxford University; 2003.
- [12] Clancy, D., Breen, J., Thorne, F., Wallace, M.; *A stochastic analysis of the decision to produce biomass crops in Ireland*. Biomass and Bioenergy 2012; 46: 353-65.
- [13] Vasallo J.M.; *Traffic Risk Mitigation in Highway Concession Projects*. Journal of Transport Economics and Policy, Volume 40, Part 3, September 2006; 40(3): 359-81.
- [14] Gómez-Lobo, A., and Hinojosa, S.; *Broad Roads in a Thin Country: Infrastructure Concessions in Chile*. Research Paper 2279, World Bank, Washington, D.C.; 2000.
- [15] Hahn, J.; *Private Participation in the Infrastructure Programme of the Republic of Korea*. Transport and Communication Bulletin for Asia and the Pacific, No. 72, United Nations Economic and Social Commission for Asia and Pacific, Bangkok, Thailand; 2003.
- [16] Lewis, C. M., and Mody, A.; *The Management of Contingent Liabilities: A Risk Management Framework for National Governments*. In *Dealing with Public Risk in Private Infrastructure* (T. Irwin et al.), World Bank, Washington, D.C.; 1997.