# INVESTMENT IN DISTRIBUTED ENERGY GENERATION: A PRESENT-VALUE MODEL OF DIFFERENT TECHNOLOGIES[1]

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## Abstract

This paper introduces a present-value model to assess investment projects in distributed energy generation. Distributed energy generation is one of most challenging trends in future energy policy. However, a critical problem in energy generation planning at the micro level is the lack of sophisticated tools for decision makers to assess the profitability of investments in distributed generation. There are a number of ways to distribute energy generation, which at the general level makes the analytical description of investment project impossible. The idea of the present study is to classify distributed energy generation technologies into three classes with respect to the distance of location and to the intensity of need for energy. Seven typical cases in these classes are modelled based on case data from the South-Ostrobothnia district. As a limitation, only direct cash flows are taken into consideration to assess economic profitability of distributed generation in each case. A present-value framework is adopted to get an estimate for the discounted cost of energy. The results are discussed from the point of energy policy. The study is a part of the *Densy* (Distributed Energy System) project carried out at the University of Vaasa.

**Key words:** distributed energy generation, present value, investment project assessment, cost of energy.

**JEL classification:** Q42, G30, G31.

## 1. Introduction

Worldwide the energy generation industry is undergoing a substantial process of restructuring, with an emphasis on the introduction of competition in the generation sector (Chaton & Doucet, 2003). Competition will lead to better incentives, both in the use of existing resources and in future investment decisions. In the future, distributed generation of energy provides an important opportunity for the energy system (Curney, McNally & Smith, 2003). Distributed generation involves modular, self-contained energy generation located near the point of use. In addition, the energy system is going to experience a major transformation from a fossil to a renewable basis with the next decades (Steininger & Voraberger, 2003). This is expected to be due less to the exhaustion of fossil fuels than to the lack of absorption capacity for the by-products of fossil fuel use. Political bodies have begun to set targets for this transformation. For example, the European Commission (1997, p. 7) in its White Paper on Energy sets an overall EU target of doubling the share of renewables by 2000.

These opportunities and challenges will lead to a need of new sophisticated tools for assessing investments in energy generation. There are several approaches to develop such tools. Chaton (1997) and Chaton & Doucet (2003) present a linear programming model to the problem of optimal expansion planning in the face of uncertainty. The model explicitly accounts for equipment availability and load duration curves in selecting optimal investment. Chomitz & Griffiths (2001) present a computational methodology for assessing the evolution of wood-fuel supply costs and the spatial distribution of biomass in a case of a woodland setting. For an exogenously specified demand, the model simulates, period by period, the extraction, regeneration, and transport of wood fuels. Steininger & Voraberger (2003) carried out an inquiry into investment, operating and

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financing costs of biomass energy use systems, to allow a standardized comparison of technologies. Then, they employ a computable general equilibrium model of economy to quantify the impacts of fostering the use of distinct biomass energy technologies. For distributed power generation, Franceschi, Condela & Eber (2003) present a framework for the potential economic benefits of emission offsets and greenhouse gas reductions and how they affect the discounted cash flows of a combined heat and power project.

Deng (2005) presents an option-based valuation framework of electricity generation capacity to take into consideration the electricity price spikes. The framework provides a tool for merchant power plant owners to perform hedging and risk management. Diederen, van Tongeren & van der Veen (2003) apply a real options framework to improve estimations given by conventional present-value calculation for the profitability of energy-saving investments. In two types of technology, they estimate hurdle rates for investments using simulated future revenue streams, given uncertainty regarding energy prices and energy tax policies. Kumar, Cameron & Flynn (2002) determine the power cost and optimum plant size for power plants using three biomass fuels. All biomass cases showed flatness in the profile of power cost versus plant capacity. This occurs because the reduction in capital cost per unit capacity with increasing capacity is offset by increasing biomass transportation cost as the area from which biomass is drawn increases. In summary, there are a number of alternative approaches to analyse the economic consequences of energy investments. *However, there are no such easy-to-use capital budgeting models supporting different types of investors (farms, manufacturing firms, municipalities) to assess profitability of investments in distributed energy generation based on renewables.* The objective of this study is to introduce such a model.

Distributed energy generation can be operated as independent, stand-alone sources of energy or it can be used in conjunction with established grid power. Distributive energy technologies can be a major asset in transforming the energy system from the use of fossil fuels to renewables (Curney, McNally & Smith, 2003). Thus, they provide us with a good option with respect to sustainable development (Alanne & Saari, 2005). These kinds of technologies provide obvious benefits over centralized energy generation to facility owners, the environment, and the public at large (Franceschi, Condela & Eber, 2003). Some of the benefits include fossil energy savings, increased energy efficiencies through simultaneous power and heating recovery, increased power quality and reliability, elimination of transmission and distribution losses, emission offsets, and greenhouse gas reductions. To costs to design, purchase, and install distributed energy systems are however critical and prohibitive factors in the overall economics of distributed power options (Rastler, 2005). Financing alternatives, high operational efficiency, and low- or zero-fuel costs, but the fact remains that total capital equipment costs are expensive and need to be significantly reduced for larger market impacts to occur.

Thus, distributed energy system technologies provide an important opportunity of the future because they own many benefits. These technologies provide power closer to the point-of-use leading thus to a potential to save customers money. They also provide back-up reliability and help utilities minimize investments in new facilities to meet peak loads. However, in practice it is difficult to monetize the benefits of the systems because many benefits are both time- and location-specific (Rastler, 2005). In addition, competitive markets have not been able to monetize these benefits and many utility business units are disaggregated into separate energy supply, transmission, and distribution entities, compounding difficulties to capture and monetize value from decentralized systems. *The purpose of this study is to construct a model to help to monetize the benefits of an investment on distributed energy generation.* For this purpose, the framework is applied to eleven typical cases in distributed energy systems to pay attention to the type and location of the project. These cases are selected to cover the different distributed energy technologies from the perspective of the distance of location and to the intensity of need for energy. In short, these cases are classified into the following three classes: 1) energy generation in conjunction with a manufacturing firm (five cases), 2) stand-alone generation (four cases), and 3) generation owned by a municipality (two cases).

Capital budgeting models may be crucial in supporting capital expenditure decision-making in projects of distributed energy generation for many reasons. First, these projects typically require large outlays of funds. Second, firms must find out the best way to raise and repay these finds. Third, these kinds of projects require a long-term commitment from the side of the firm.

Cooper, Morgan, Redman & Smith (2002) present a review of empirical studies on capital budgeting methods. Typically, these studies show that the discounted cash flow techniques are the most popular methods for assessing projects, especially the internal rate of return. However, many firms still use the payback method as a backup or secondary approach. Biezma & San Cristobal (2006) present a description of project evaluation techniques in the design of a combined heat and power (CHP) unit. Following Cooper et al. (2002) they state that virtually the only criteria used have been the net present value, internal rate of return, and payback period. They also present a case where the different techniques are applied to the selection between two CHP units.

Biezma & San Cristobal (2006) show, that traditional investment criteria are useful in analysing CHP projects. In this paper, these techniques will be applied to investment projects on distributed energy generation. It is the idea to show that these criteria provide us with useful planning tools in practical decision making *at the micro level* of single power generation units. However, these criteria are also applicable when analysing the profitability of such investments *at the macro level* for designing an energy policy of a country. The present approach is based on the present-value framework allowing to use discounted value of project, internal rate of return and payback as a criterion for investment. The analysis is limited to direct monetary flows from the distributed energy investment. All the externalities are excluded from the analysis. For externalities of biomass for electricity production, see Saez, Linares & Leal (1998). They assess the effect of human health, $CO_2$ balance, soil erosion, non-point-source pollution, and employment on the total cost of biomass and coal electricity. See also Bergmann, Hanley & Wright (2006). In addition, all the models are considered under certainty. See Rawn & Skytte (2000) for an inclusion of uncertainties in energy-economic modelling.

This paper is organized as follows. This introductory section presented the background of the study based on the challenges and the call for new investment assessment methods provided by rapidly increasing distributed energy generation based on renewables. The general structure of the model is briefly presented in the second section. The model is based on Excel worksheets and is constructed together with the management from the case units to ensure relevance, easiness-of-use and commitment. The approach utilizes conventional present-value approach without any externalities or uncertainty. However, it is possible to run sensitive analysis with the model. The third section introduces the eleven cases from the three classes of distributed energy generation technologies while the fourth section reports case results at the micro level. Finally, the last section associates the case results with the discussion of energy policy and summarizes the study. Supporting the conclusion drawn by Rastler (2005), the results show, with current estimates of distributed energy costs and benefits, only fewer cases of cost-effective technologies.

## 2. The structure of the Densy model

### *2.1. Technologies in the Densy model*

The capital budgeting model to be presented in this study is called the *Densy* (Distributed Energy System) model. The Densy model is a decision support system designed to provide information and forecasts to the decision makers (DM) in waste-intensive private firms, farms, and municipalities, to help them in their strategic decision making about energy generation. The model allows the user to simulate the effects of alternative factors on different distributed energy generation projects and to observe their predicted impacts on the economic viability of the investment project. In the model, economic viability is calculated by general cash-flow-based investment criteria, including Net Present Value (NPV), Internal Rate of Return (IRR) and both undiscounted and discounted Payback Period (PP). These widely used measures for accepting or rejecting investment projects were selected as criteria because they are easy to utilize and well-known by the managers in the target organizations (see Cooper et al., 2002). The main analysis in the Densy model is based on the estimation of the theoretical amount of generated energy and on alternative ways to calculate the price of generated energy, which give an estimate of the revenue flow. In addition, the cost flow is assessed on the basis of the technology applied. These flows are then used to get an estimate for the criteria. The general framework of the Densy model is illustrated in Figure 1.

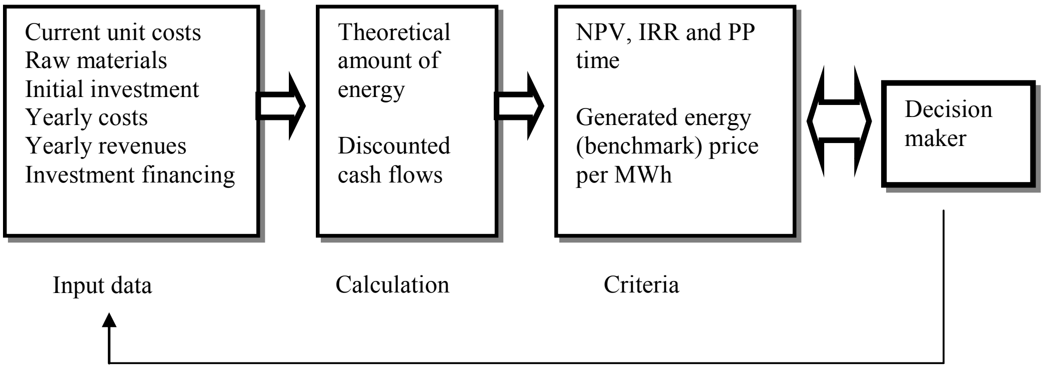

Fig. 1. The general framework of the Densy model

It is not possible to develop a general capital budgeting model that can be without customization applied in every distributed energy case, because the technologies and backgrounds of the investment units differ from each other. From the perspective of the Densy model, distributed energy generation cases can be divided into three different classes, by the technology (the way in which they generate energy) way and by the ownership structure. The three classes are: 1) energy generation in conjunction with a manufacturing firm, 2) stand-alone generation, and 3) generation in a unit owned by a municipality. Each of these classes has some unique characteristics, which affect how the revenue flows (amount and price) and the cost flows are built up in the model. The three classes are discussed in detail in the following sections below.

In the first class, *biogas energy generation in conjunction with a manufacturing firm,* the economic profitability of the investment project is examined for a case where the firm is assumed solely to own the energy generation unit. Thus, current waste treatment and transport costs as well as cost of outside energy (which are removed if the firm applies own energy generation) are technically considered as revenues (decrease in costs) in the calculation. In addition, benchmark prices (per MWh) for the current energy price and for the biogas energy generated by the new plant are calculated. Prerequisites for adopting this class point of view are typically the following: 1) the firm produces lot of waste which can be used as a raw material in a biogas production, 2) current waste treatment and transport costs are high, and 3) the firm has big electricity and/or a heat need.

The second class examines *the stand-alone generation units*. This approach assumes that there is an independent distributed energy generation unit. This kind of unit is usually located near of the point where energy is consumed by energy intensive firms. The specification of the Densy model in this class is made from the independent entrepreneur point of view. Thus, the prices of raw materials and energy sales are valued at regional market prices. This class highlights the economic profitability of the investment project because these kinds of case units generally operate in competitive energy market. For this case, energy benchmark prices are not calculated, since it is assumed that these units do not have any specific bindings to any firm purchasing energy at a certain price. They are assumed to act as independent units.

The third class, *municipal generation unit* regards the energy investment unit more as a waste disposal plant than an economically profitable biogas plant. In these kinds of cases the specification of the Densy model will be made according to the principles of a non-profit investment project that means that yearly revenues are assumed to cover operating costs, deprecations, and interests. However, a required rate of return defined for a municipal owner is assumed in discounting. Usually the main revenue source in these kinds of municipality-owned plants is the gate fees of incoming wastes. Naturally, corporate taxes are excluded from calculation. As a result, also processing cost of raw materials per incoming waste ton is reported.

### *2.2. Framework of the Densy model*

The Densy model is implemented in a spreadsheet program framework, *Microsoft Excel*, using formulas and *Visual Basic* macros. The core of the model consists of three main sheets: 1) current costs sheet, 2) energy sheet, and 3) investment calculation sheets. These sheets form the main structure of the Densy model. In addition, the model also includes separate sheets for the results, the sensitivity analysis, the evaluation of the economic forecasts of the investment unit, and the raw material data.

The *current costs sheet* is only applicable when examining energy generation in conjunction with a manufacturing firm (class 1). In the sheet, all current waste treatment and transport costs are given as inputs for the model. The costs are allocated to each waste type by their yearly-generated amounts (default). In practice, these costs are not necessarily generated in relation to the amount (weight) of waste. In some cases costs could be better allocated by some other factor, for example by the time used that is consumed by treating and transporting of each waste type. However, taking account of the general roughness of calculation accuracy in the Densy model (for example, inaccuracies in forecasting), this kind of weight-based allocation is considered as a sufficient approximation by the management of the case firms. Finally, the desired waste types for the distributed energy generation are selected and their proportion of total costs is calculated. In this sheet, information of the current energy sources, prices and yearly consumption data are given to calculate the benchmark price of the replacement energy.

The first part of the *energy calculation sheet* makes it possible to perform a rough analysis of the regional waste energy potential and its sources if the waste amounts are available. In the second part, the theoretical biogas potential of the selected waste types (materials) is estimated. The calculation of biogas production is based on the proportions of total solids, volatile solids and methane production potential of the waste materials. The amount of available energy potential is calculated using the overall amount of biogas and an assumption of its methane content. Possible benefits of co-digesting different type wastes are excluded from the calculation. The produced biogas is then converted to the user-desired energy form with different efficiency multipliers. Possible energy forms are heat, combined heat and electricity, vehicle fuel and other use. The own energy need of the biogas plant can be either subtracted from the own production or it can be bought from the outside. The residual energy is called free energy, which can be sold to the outside of the plant or used as a replacement of outside energy in manufacturing firms. This energy is always case-specifically valued in the model. If the vehicle fuel form is selected, then the model calculates the amount of the regular vehicle fuel equivalent liters.

The *investment calculation sheet* consists of input data of all revenues and costs, which are related to the energy generation investment. The actual investment calculations are prepared using the conventional discounted cash flow technique. Typical cash flows for such an investment are initial investment, government's investment grant and all regular yearly based operating costs and revenues. For the discounting procedure, the Densy model uses a weighted average cost of the capital (WACC). This kind of WACC is generally used in practical capital budgeting. In the same way, the Densy model assumes that typically for such an expensive investment as an energy generation unit both debt and equity are needed. In addition, only positive income taxes are taken into account in the cash flow projection. Thus, all negative taxes, tax refunds, are excluded from the analysis.

The cash flow concepts used in the Densy model are *traditional*. This means that cash flows are calculated on an accrual basis. The net cash flow is defined as cash receipts (earnings) minus cash payments (costs and taxes) over a given period of time. The model calculates the net cash flow before and after the income taxes. For calculating the investment criteria (NPV, IRR and PP) the traditional cash flow after taxes is used, if the tax rate is applied. In addition, all the investment grants are handled as a deduction of the initial investment which gives a net investment concept. In the calculation of the yearly net cash flow the following definition is used:

Net cash flow = Earnings before interest, taxes and depreciation (EBITD) – Taxes – Net Investment (only in the first year).

The *results sheet* reports in addition to general investment criteria (NPV, IRR and PP), the price of the generated energy in several alternative ways. The production cost of energy (heat and electricity) per megawatt hours (MWh) is reported. The energy price calculated with only operating costs and only investment depreciation is also presented. In addition, the break-even energy selling price per produced MWh is reported (energy cost price). This price includes all operating costs and revenues (without energy selling revenues). In municipality-owned power generation, the Densy model also calculates the processing cost of raw materials per incoming waste ton. This result can be for example used for fixing gate fees for incoming wastes.

When the energy generation in conjunction with a manufacturing firm is in question, the Densy model calculates the benchmark price based on the present energy price. In this benchmark price (besides current energy costs) the current waste treatment and transport costs are included for that proportion which would be removed if the firm introduced an own energy generation unit. If the own energy generation can not satisfy all the energy demand of the manufacturing firm in question, then the difference between the amounts of own generation and overall demand is valued with current outside energy prices and added to the benchmark price. In the Densy model, the benchmark price also takes account of the tax reduction gained by the firm for the sake of own generation.

When calculating the energy price of the own energy generation, the Densy model takes into account all the costs and revenues which are related to the new generation form. In this way a comparable energy price is obtained to the current and to the distributed generation alternatives. The energy costs are calculated separately for the both alternatives for every planning year using discounted prices. However, the depreciations of the investment expenditure are not discounted because they are computational (book) expenses.

The *sensitivity analysis sheet* makes it possible to the user of the Densy model to examine the sensitivity of the results for the investment criteria and energy price calculation, to certain input data parameters. This sensitivity analysis is based on a *ceteris paribus* principle limited to a change in one individual parameter value at a time. In the model, the effect of a change in the following parameters can be simulated: cost of equity capital, net investment, variable costs, fixed costs, and revenues.

In the *economic forecast sheet*, the economic development of the biogas plant can be estimated with a separate tool (a financial model) which comes along. With the help of this tool, the forecasts of the income statements and balance sheets for the future years are obtained. In this analysis, the depreciations of different fixed assets categories can be calculated for different depreciation times as required by the Accounting Act. Furthermore, this sheet includes a specific financing calculation procedure which helps the user of the Densy model to estimate the effect of investments on the financing need and enables planning of the annual amortization level of the liabilities.

The *raw materials data sheet* includes the parameters that describe the total solids, the volatile solids and the methane production potential of each waste material. These raw material data are used by the energy calculation sheet. There are built-in parameters in all to 35 waste fractions which are adjustable by the user of the Densy model. In addition, the user can also add new raw materials to the database in the sheet.

## 3. Energy generation investment cases in three technologies

### *3.1. Rationale for case selection*

The cases considered in this study are selected to cover extensively the potential distributed energy generation forms in the district of South-Ostrobothnia. According to Hyttinen (2005: 63), typical forms (technologies) in distributed energy generation are determined by the following factors: the demand of energy, the remoteness of location, the amount of local renewables and the current energy infrastructure. In Figure 2, the regions where the distributed energy generation technologies can be potentially found are presented on the dark grey area. In this figure, the energy demand of the surrounding light dark area should be satisfied with centralized energy generation technologies. The white spots in the figure are examples of typical cases which are examined in this study. Consequently, the remoteness of location (periphery versus central) and energy demand dimensions (low versus high) have been taken into account as the main criteria in the case selection.

Figure 2 also shows that these typical cases also implicitly refer to biogas technologies for business environments of a different size. The results of these kinds of typical micro cases make it possible to generalize certain results of distributed energy generation opportunities at the macro level.

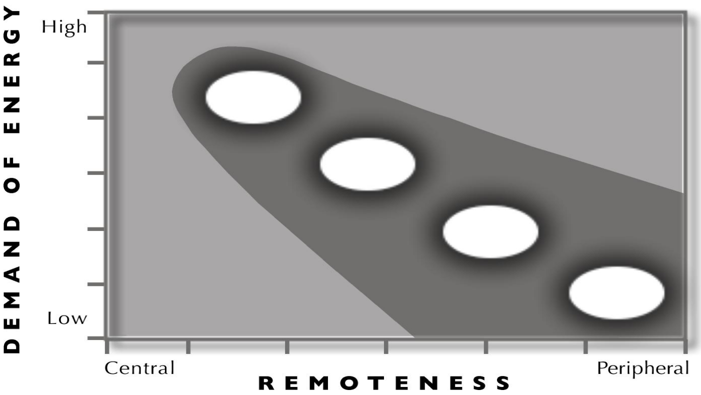

Fig. 2. Typical classes of distributed energy generation (Hyttinen, 2005)

### *3.2. Case description*

In the present study, the Densy model is applied to eleven typical cases, which are summarized below. These eleven cases are classified to the three different classes of distributed energy technology discussed earlier. The case-specific data for these cases (the values for the parameters) have been prepared along with the management of the case units. However, these case units are not willing to publish exact numerical data and will be disguised, when they are analyzed in this study. Thus, the case-specific data are considered here only at a rough level and a numerical code is used to identify the case in question.

*First class of cases*

First, the following cases of energy generation in conjunction with a manufacturing firm have been analyzed by the Densy model:

1.a. *A medium-sized co-generation biogas plant owned by a large food processing firm*. The main raw materials in biogas production are certain own waste fractions available in a large quantity. In addition, manure and sludge from the local farms participated in the project are used as raw material in the energy generation. The generated biogas is converted to the heat and is valued on the price of heavy fuel oil produced energy, which is currently the most expensive heat production source of the case firm. However, the produced energy is only enough to cover approximately one-third of heat used by the firm.

1.b. *A small unit of one farm* that is located in South-Ostrobothnia countryside. This case plant uses *pig sludge* and *reed canary grass* as the raw material. The gas is used for the satisfying of the own heat and electricity demand of the case farm. The energy that exceeds the heat demand of the farm is valued on the price of light fuel oil. This energy can be used as a replacement of oil in the heating of a green house.

1.c. *A small unit of one farm* in countryside that uses *dry fermentation technology* in biogas production. Selected biomass composition consists of the farm's own straw and chicken manure. The heat and the electricity generated by the plant are just enough to cover the own energy consumption of the farm.

1.d. and 1.e. *A biogas plant of a middle-sized manufacturing firm* that uses in energy generation own waste fractions, sludge of the municipal sewage treatment plant, waste of another manufacturing firm and pig sludge. The energy which exceeds the annual demand of the firm is sold as heat to the energy intensive industry in the neighboring area. Two alternative cases are prepared for the firm, which differ in the usage of biogas. In the first case analysis (1.d) biogas is used in CHP production and in the second case analysis (1.e) mere heat is produced. The analyses for these cases slightly differ from each other in the amount of initial investment outlay and in the valuation of generated energy.

*Second class of cases*

There are in all four cases in the present study which belong to the class of the stand-alone energy generation unit. In these cases, raw materials and energy selling prices are valued at regional market prices, when case-specific data are not available. The rest of the general assumptions applied in these cases are presented in the next section.

2.a. *Medium-sized biogas plant that is located in the vicinity of a large food processing firm* (case 1.a). This plant uses two waste fractions of the firm and large amount of manure and sludge from the local farms. From this basic case plant three separate analyses have been made as follows.

In the first case analysis (2.a) all energy is sold back to the firm along the gas pipe. The firm is assumed to use the gas as a replacement of heavy fuel oil in the heat production. For the attractiveness of bio energy alternative, the energy price per the units needed to produce one MWh of heat is set 5% lower than the price of an MWh generated by oil. The generation unit pays both transportation costs of the farm wastes to the plant and the return loads of the hydrolysis residue back to the farms. The gate fees are paid only by the large food processing firm.

The second case analysis (2.b) only differs in such a way that the gate fees will be collected also from the farmers (5 euros/incoming ton).

In the third case analysis (2.c) the value of energy generation is calculated on the assumption that the produced methane is purified and pressurized to the vehicle fuel. The numerical analysis is prepared without any gate fees from the farmers. The vehicle fuel is valued at a wholesale price so that an additional investment of a required distribution center or distribution costs are not taken into account in the calculation. In addition, some revenues are generated from the selling of purification by-product, $CO_2$, to the industry.

2.d. *A small-sized joint biogas plant of several farms* located near the biggest town in South-Ostrobothnia. In this case, raw materials contain only chicken, pig and cattle wastes from the participating farms. The gate fees are collected from the farmers. Biogas is refined to the vehicle fuel and is valued on same way as in case 2.c.

*Third class of cases*

Finally, the present study deals with the following two cases analyzed from the perspective of a municipality-owned energy generation unit.

3.a. *Municipal biogas plant* that is a waste disposal firm owned by several municipalities in the South-Ostrobothnia district. The bio wastes of households, which are currently composted, and the refinery sludge from the industry, are used by the plant as the raw materials in biogas production. The gate fees are based on agreements with municipalities so that the main task of the Densy model is to estimate the economic viability of the plant with these given prices.

In the first case analysis (3.a) the generated heat and electricity are sold to the other units of the waste disposal firm at the local market prices.

In the second case analysis (3.b) the produced gas is refined to the vehicle fuel and is valued on the same basis as in case 2.c.

### *3.3. General assumptions used in the cases*

The calculation of the investment criteria (NPV, IRR and PP time) is based on a set of general assumptions identical for each case. These assumptions are briefly summarized below. The economic lifetime of a biogas plant is estimated to be 15 years. For the depreciation, the straight-line method is used. The amount of the investment grant is assumed 30% of the initial investment and is calculated assuming that 80% of costs are acceptable for subsidy. Taxes, when applicable, are calculated using the Finnish corporate tax rate (26%).

The calculation of WACC is based on several assumptions. The share of debt in financing is assumed 60% of the net investment. This share approximately corresponds to the average share of debt in Finnish firms. In addition, it has been assumed that a payback time of the debts is the same as the economic lifetime of the investment (15 years). The amortizations are assumed level. The fixed cost of debt (3.5%) is based on the 12 months Euribor interest rate plus 0.7% as the interest rate margin of the creditor. The cost of equity capital is set to a moderate level of 10 %. It is assumed that because of positive externalities, specifically reputation benefits, from biogas production the cost of equity is slightly lower than in normal investment projects.

In the most of the cases, the cost of biogas plant investments are estimated with the help of information from recently constructed biogas plants in Finland. The main criterion for choosing an investment cost estimate of a comparable plant was the reactor size of the plant. When any appropriate data of comparable plants constructed earlier, were not available, a rough estimate of the investment cost was requested from a large Finnish plant supplier.

The operating costs are roughly estimated in a certain relation to the total investment because any accurate cost information of realized projects was not available. On the basis of the estimates given by the plant suppliers the annual operating costs are usually 5-15% of the initial investment. For simplicity, in the calculations of the cases 8% has been used as an estimate. These costs have been divided into variable and fixed costs so that the share of variable costs in total cost is 10%. It is assumed that these operating costs will cover the chemicals, water, other materials, salaries, insurance premiums, real estate taxes, maintenances and other similar running costs. In addition to these costs, some costs are separately estimated. These costs include the own energy usage of the plant, the transport costs of raw materials and hydrolysis residue, and debt financing costs.

## 4. Results of the case analyses

The economic viability analyses of the eleven cases described above are carried out by the Densy model on the given assumptions. For each case, the IRR calculated for the equity is reported. This rate gives an estimate of the financial profitability of the case project in question. If the IRR is negative, the case project gives a negative yield. For a negative IRR, a sensitivity analysis is made to show how many percentage 1) the government investment grant, and 2) the rate of gate fees should increase to attain a zero IRR. For any economic decisions, a zero IRR may be the minimum requirement for accepting a project. In addition, it is also analyzed how many percentage the increase should be to reach the assumed (required return) cost of equity capital (10%).

### *First class of cases*

Table 1 shows that the IRRs for all the cases in the first class (energy co-generation) are positive except for case 1.a. *Even though the IRRs are positive, none of them indicate a return higher that the required rate of return of equity*. This factually means that if the investment project cases are only assessed purely by their economic profitability, they are most likely to be rejected by the decision makers in business firms. However, considering that current waste treating (for example environment taxes) and energy (especially fuel oil) costs are increasing rapidly, these co-generation solutions are reaching a better economic feasibility all the time. In cases 1.d and 1.e, a minor increase (15% and 11% respectively) in gate fees would make the own energy co-generation to a competitive alternative (to reach a 10% IRR).

A simulation with the Densy model shows that the negative IRR in case 1.a (-3%) is mainly caused by that the cost savings reached by the case firm via switching to own energy generation are relatively low. The case firm has currently a cost-effective waste-treating system and favorable negotiated fuel oil contracts, which explain quite low savings. In order to reach a zero IRR in fifteen years planning period, the original initial investment subsidy must be raised by 67%. However, this increase should be as high as 208% to get the required rate of return for equity.

Table 1

Profitability of the energy co-generation cases (the first class of technologies).

| | Case | | | | |
|---|---|---|---|---|---|
| | 1.a | 1.b | 1.c | 1.d | 1.e |
| | | | | | |
| Internal rate of return, IRR | -3% | 6% | 4% | 7% | 7% |
| | | | | | |
| Subsidy increase (%) to make IRR = 0 | 67% | | | | |
| Gate fees increase (%) to make IRR = 0 | n/a | | | | |
| | | | | | |
| Subsidy increase (%) to make IRR = 10% | 208% | 56% | 83% | 56% | 50% |
| Gate fees increase (%) to make IRR = 10% | n/a | n/a | n/a | 15% | 11% |

*Second class of cases*

Table 2 presents the results for the cases based on the second class of technologies (stand-alone energy generation). Of these cases, only case 2.c has got a reasonably high IRR, which makes vehicle fuel alternative economically attractive. However, since there does not currently exist in Finland any infrastructure for bio-fuel vehicles, the still open issue of pricing and taxation of vehicle fuels limits certainly the practicability of this result. *Cases 2.a and 2.b have both a negative IRR reflecting an economically unprofitable investment project.* The basic reasons for the negative figures are the same as in case 1.a. The levels of gate fees are set not to exceed the current waste treating costs of the manufacturing firm. However, collecting 1% higher gate fees also from the farmers in 2.b improves economic viability to the lowest acceptable level (IRR = 0).

This result indicates that the gate fees from the farmers play a major role in these cases and have a substantial effect on the required amount of investment subsidy (93% versus 3%). Even though, a substantial improvement (87%) in the gate fees is needed to reach the assumed cost of equity capital, which seems to be elusive. Case 2.d, which contains only the sludge and slurries from the farms with gate fees included, IRR is negative (-4%). This signals that without gate fees from the industry wastes the energy generation project is unprofitable even if the biogas is refined to a high margin vehicle fuel.

Table 2

Profitability of the stand-alone generation cases (the second class of technologies)

| | Case: | | |
|---|---|---|---|
| | 2.a | 2.b | 2.c |
| | | | |
| Internal rate of return, IRR | -4% | -1% | 13% |
| | | | |
| Subsidy increase (%) to make IRR = 0 | 93% | 3% | |
| Gate fees increase (%) to make IRR = 0 | 27% | 1% | |
| | | | |
| Subsidy increase (%) to make IRR = 10% | 220% | 179% | |
| Gate fees increase (%) to make IRR = 10% | 150% | 87% | |

*Third class of cases*

Finally, Table 3 shows the results of municipal energy generation unit cases (the third class of technologies). *For the current gate fees for incoming waste and for the current net initial investment, the IRRs in both cases 3.a and 3.b seem to be positive.* In case 3.b, the IRR equals the required return of equity which may make it acceptable in the eyes of investors. However, because the incoming waste combination is not specifically optimized for energy generation, the amount of produced energy is relatively small and so the revenues from energy selling are modest. This explains why in case 3.b the production of vehicle fuel increases the IRR only by 4% unit (10% versus 6%), which is a low value if it is compared to the increments between cases 2a and 2c (-4% versus 13%).

Table 3

Economic profitability of the municipal generation cases (the third class of technologies)

| | Case: | |
|---|---|---|
| | 3.a | 3.b |
| | | |
| Internal rate of return, IRR | 6% | 10% |
| | | |
| Subsidy increase (%) to make IRR = 0 | 80% | |
| Gate fees increase (%) to make IRR = 0 | 10% | |

## 5. Summary and discussion

The purpose of this study was to construct a model to help to monetize the benefits of an investment on distributed energy generation. For this purpose, the Densy framework was applied to eleven typical cases in distributed energy systems to pay attention to the type and location of the project. These cases were selected to cover the different distributed energy technologies from the perspective of the distance of location and to the intensity of need for energy. In short, these cases were classified into the following three classes: energy generation in conjunction with a manufacturing firm (five cases), stand-alone generation (four cases), and generation owned by a municipality (two cases). In general, the results of the cases are parallel with Rastler (2005). *With current estimates of distributed energy costs and benefits, only a few of the technologies are economically profitable.*

Four of the five cases in the first class (co-generation) show a positive figure for IRR but their profitability stay below the required return of equity (10%). However, if current waste treating (for example environment taxes) and energy (especially fuel oil) costs are increasing rapidly, these co-generation solutions are reaching a better economic feasibility all the time. When the plant is based on a co-generation by a middle-sized manufacturing firm that can utilize waste also from other such firms, a reasonable profitability will reached with a minor increase of current gate fees (10-15%). However, when small units of single farms are considered, a remarkable increase in investments grants are required to reach profitability attractive to investors.

Three of the four cases in the second class (stand-alone generation) show a negative IRR for current revenue and cost estimates. Only the technology case where the produced methane is purified and pressurized to the vehicle fuel had an IRR higher than the required return of equity. In addition, this profitability was reached without any gate fees from the farmers. This makes the vehicle fuel alternative economically attractive although there in Finland is no infrastructure for bio-fuel cars. In order to make the three other technologies profitability enough, an unreasonable high increase in investment grants or gate fees are required. However, if gate fees are collected from both manufacturing firms and farms, only a marginal increase in gate fees is needed to reach a positive profitability. *Thus, gate fees play an important role in these technologies.*

Both of the two cases in the third class (municipal energy generation) are economically profitable for the current circumstances. Again, if the produced gas is refined to the vehicle fuel, profitability close to the required return of equity is reached. If this is not done, a considerable increase in investment grant or a minor increase in gate fees is needed to reach the sufficient return. *Thus, municipal distributed energy generation has a potential but is limited by the lack of infrastructure for bio-fuel vehicles in Finland.*

When *the macro level* is considered, the results of the study support the conclusion that distributed energy generation in Finland has promising opportunities in the future. There are little over thousand potential manufacturing firms which are large enough and which may have suitable waste fractions for distributed energy generation comparable to the present cases. These firms could utilize a co-generation technology or could be acting as a partner in a stand-alone generation which could partly satisfy own energy need of these firms. In Finland, there are approximately seventy-five thousand farms. A major part of these farms are approaching required economic profitability to build up own energy generation in the near future, if the current energy costs keep rising. Generally, farms seem to have enough waste resources to replace all outside energy with own production. This implication would have far-reaching consequences to periphery energy infrastructure (see Hyttinen, 2005). For the municipal energy generation solutions, in Finland there could be opportunities for 40-50 plants of the same size as in the present cases. They might be economically feasible alternatives, when the nationwide vehicle fuel infrastructure is being built.

Thus, it is expected that the distributed energy generation technologies will have a large potential in the future. Vartiainen, Luoma, Hiltunen and Vanhanen (2002) have carried out a study of the future of distributed energy production in Finland. They state that in distributed heat production, biomass is already used widely in Finland. The potential of biomass utilisation is mainly restricted by the availability of fuel at a competitive price. Solar heating and heat pumps are not yet competitive with biomass, but their potential is also great. Of the CHP technologies, gas and diesel engines are the most competitive at the moment. Moreover, micro-turbines are feasible in small (below 100 kW) scale CHP. Fuel cells are expected to be significant in the long term, as their price is assumed to be reduced with mass production. The growth of all CHP technologies is restricted by the availability and price of the fuel. In Finland, CHP systems based on biomass fuels will be significant in the future. *The results of the present study show that these technologies can be made also economically profitable.* However, it is required that the energy generation plants operate cost-efficiently, collect high gate fees, and get significant investment grants from the government.

The present analysis is exposed to many limitations that can be relaxed in forthcoming studies. First, the model is based only on direct monetary flows and excludes all externalities (see Saez, Linares & Leal, 1998). Second, the model is deterministic excluding uncertainties (see Rawn & Skytte, 2000). Third, there are limited amount of data to get exact and reliable values for the parameters of the model. Thus, many rough approximations are used in analyses. Fourth, the analysis is limited to only three typical technologies of distributed energy generation. Fifth, the model considers the energy contents of all raw materials separately and does not take account synergic effects from combinations of certain materials. Finally, there are accounting limitations such as assumptions on the life of investment, depreciations, and amortizations, which are easy to relax in the analysis.

## References

1. Alanne, K. & A. Saari (2005). Distributed Energy Generation and Sustainable Development. Renewable and Sustainable Energy Reviews. In press.
2. Bergmann, A., N. Hanley & R. Wright (2006). Valuing the attributes of renewable energy investments. Energy Policy. 34. 9. 1004-1014.
3. Biezma, M.V. & J.R. San Cristobal (2006): Investment Criteria for the Selection of Cogeneration plants – a State of the Art Review. Applied Thermal Engineering. 26. 583-588.
4. Chaton, C. (1997). Fuel Price and Demand Uncertainties and Investment in an Electrivity Model: A Two-period model. Journal of Energy Development. 23. 1. 29-58.
5. Chaton, C. & J.A. Doucet (2003). Uncertainty and Investment in Electricity Generation with an Application to the Case of Hydro-Quebec. Annals of Operations Research. 120. 1. 59.
6. Chomitz, K.M. & C. Griffiths (2001). An Economic Analysis and Simulation of Woodfuel Management in the Sahel. Environmental and Resource Economics. 19. 285-304.
7. Cooper, W.D., R.G. Morgan, A. Redman & M. Smith (2002). Capital Budgeting Models: Theory vs. Practice. Business Forum. 26. 1, 2. 15-19.
8. Curney, B., M. McNally & M. Smith (2003). Distributive Energy. Montana's New Frontier. Montana Business Quarterly. 41. 4. 15.
9. Deng, S-J. (2005). Valuation of Investment and Opportunity-to-Invest in Power Generation Assets with Spikes in Electricity Price. Managerial Finance. 31. 6. 94-114.
10. Diederen, P., F. van Tongeren & H. van der Veen (2003). Returns on Investments in Energy-saving Technologies Under Energy Price Uncertainty in Dutch Greenhouse Horticulture. Environmental and Resource Economics. 24. 379-394.
11. European Commission (1997). Energy for the Future: Renewable Energy. White Paper for a Community Strategy and Action Plan. Brussels. COM (97) 599.
12. Franceschi, J.M., J. Condela & S. Eber (2003). The Positive Effects of natural Capital and Tax Shifting on Cogeneration Project Economics Related to Greenhouse Gas Emissions. Journal of Structured and Project Finance. 9. 2. 40.
13. Hyttinen, T. (2005). Valoa pimeässä. Kohti energiaomavaraisuutta maaseudulla (in Finnish). Publications of the Levon-Institute. 187 p.
14. Kumar, A.., J.B. Cameron & P.C. Flynn (2002). Biomass Power Cost and Optimum Plant Size in Western Canada. Biomass and Bioenergy. 24. 445-464.
15. Rastler, D. (2005). Are Distributed Energy Resources Gaining Traction? Public Utilities Fortnightly. February. 143. 2. 48-53.
16. Ravn, H.F. & K. Skytte (2000). Uncertainty in Energy-economic Modelling of the Electrical Power Sector. Annals of Operations Research. 97.1. 213-.
17. Saez, R.M., P. Linares & J. Leal (1998). Assessment of the Externalities of Biomass Energy, and a Comparison of its Full Costs with Coal. Biomass and Bioenergy. 14. 5/6. 469-478.
18. Steininger, K.W. & H. Voraberger (2003). Exploiting the Medium Term Biomass Energy Potentials in Austria. Environmental and Resource Economics. 24. 359-377.
19. Vartiainen, E., P. Luoma, J. Hiltunen & J. Vanhanen (2002). Hajautettu energiantuotanto: teknologia, polttoaineet, markkinat ja $CO_2$ –päästöt (In Finnish). Gaia Group Oy. Helsinki.