Recent Development in Environmental Economics Part 1

edited by

Masaaki Kuboniwa

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Preface

It is my great pleasure to publish this volume of selected papers presented at the workshop on the Recent Development in Environmental Economics. The workshop held at Institute of Economic Research of Hitotsubashi University in Tokyo on the 19th of March, 2002 is focused on clarifying a configuration of the most recent development in environmental economics. .

The first paper presented by Professor Koide, faculty of economics, Seinangakuin University develops further a general equilibrium model by explicitly considering a materials-cycle and proposes hybrid systems of tax-subsidy sharing rules for a better materials-cycle.

The second paper contributed by Ms. Miyamoto, graduate school of economics, Hitotsubashi University clarifies a marked expansion of wind power as an important energy source in certain countries, including Denmark, and suggests its possibilities for further sustainable development.

The third paper presented by Mr. Zoltan, graduate school of economics, Hitotsubashi University clarifies significances of the role of green national accounts by fully surveying important contributions to green accounts in a well-organized manner.

The volume will be useful for all the economists who are interested in the analyses of sustainable development and environmental economics.

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Masaaki Kuboniwa

Recent Development in Environmental Economics Part 1

Materials Cycle and Tax-and-Subsidy Sharing Rules

Hideo KOIDE
Department of Economics
Seinan Gakuin University

Meeting for the Study of Satellite Systems

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Materials Cycle and Tax-and-Subsidy Sharing Rules*

Hideo KOIDE**

Abstract

This paper analyzes a general equilibrium model which takes a "materials cycle" into account, and then proposes several "tax-and-subsidy sharing rules" composed of taxes and subsidies on economic agents. A cycle of glass bottles and the cullets made of them is adopted as an intuitive example. Three representative agents are assumed in this model; a household, a retailer, and a bottlemaker. In addition, three types of externality are incorporated into the model in the form of yielding unintended marginal (dis)utility to the household, so that the three taxes and/or subsidies are at least required to internalize them in theory.

The sharing rules are chosen out of twenty-seven combinations of tax-and-subsidy and arranged with the following three steps; (i) assigning them to any two agents out of three, (ii) picking out the definite tax-and-subsidy combinations from the rules in (i) based on the signs of the net tax burden on each agent, and (iii) concluding that there are four rules that clearly assign the policies to each of the cycle parts, called "Production Side" and "Treatment Side." Each of the rules taxes to one agent on one side, and subsidizes to another agent on another side. Interestingly, these are interrelated and substitutable one another, so that the policy maker can design the policies more flexibly.

Key Words; materials cycle, sharing rules, externalities, Production Side, Treatment Side.

JEL Classification Numbers; D62, H21, Q38.

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** Department of Economics, Seinan Gakuin University, 6-2-92 Nishijin, Sawara-ku, Fukuoka-shi, Fukuoka. Tel; +81-92-823-4318. E-mail; koide@seinan-gu.ac.jp.

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1. Introduction

This paper analyzes a general equilibrium model which takes a "materials cycle" into account, and then proposes several "tax-and-subsidy sharing rules" composed of taxes and subsidies on economic agents. A cycle of glass bottles and the cullets made of them is adopted as an intuitive example. Three representative agents are assumed in this model; a household, a retailer, and a bottlemaker. In addition, three types of externality are incorporated into the model in the form of yielding unintended marginal (dis)utility to the household, so that the three taxes and/or subsidies are at least required to internalize them in theory.

The materials cycle we suppose in this paper is explained briefly as follows[1]. The bottlemaker produces bottles using labor and cullets, and these are in turn delivered to the retailer who produces beverages using labor and the bottles. The household buys the beverages and, after consumption, he/she chooses whether to return the empty bottles to the retailer, or to dump them. The latter activity causes external diseconomy.

Moreover, the returned bottles are finally taken back to the bottlemaker who recovers them to produce cullets. The use of them is supposed to be contributed to save more materials or energy in production than we have expected, so it is external economy[2]. On the other hand, the wastes, not used for the next production, are disposed by landfilling. This in turn causes external diseconomy.

The sharing rules are chosen out of twenty-seven combinations of tax-and-subsidy and arranged with the following three steps; (i) assigning them to any two agents out of three, (ii) picking out the definite tax-and-subsidy combinations from the rules in (i) based on the signs of the net tax burden on each agent, and (iii) concluding that there are four rules that clearly assign the policies to each of the cycle parts, called "Production Side" and "Treatment Side." Each of the rules taxes to one agent on one side, and subsidizes to another agent on another side. Interestingly, these are interrelated and substitutable one another, so that the policy maker can design the policies more flexibly.

The practical implications derived from this analysis are that the policy maker has much more policy alternatives than as expected in the materials cycling economy, and that he/she can propose more clear and understandable rules in combining the taxes and subsidies effectively according to the specific situations he/she faces. Although this analysis only presents a theoretical possibility indeed, it no doubt contributes to the comprehensive design and enforcement of the actual materials cycling policies.

The rest of this paper proceeds as follows. First of all, in Section 2, we present an economic model with a materials cycle, and explain the assumptions applied. The Pareto optimum conditions in this economy are derived in Section 3, while the competitive equilibrium conditions are obtained in Section 4. Comparing these conditions, we derive important equations to determine the tax and/or

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[1] Recently, Walls and Palmer (2001) examine "life-cycle" environmental problems with partial equilibrium modeling. Also, Eichner and Pethig (2001) show several combinations of policies when "green product design" matters in a general equilibrium analysis.

[2] Models of Koide (2000, 2001) apply the similar assumptions.

subsidy rates to internalize the externalities in Section 5. Furthermore, in Section 6, we discuss the tax-and-subsidy sharing rules by arranging the combinations in the way stated above. Finally, we conclude this analysis in Section 7.

2. Model

In this section, we present a general equilibrium model associated with a materials cycle, taking glass bottles and the cullets as the materials in circulation. We assume three representative economic agents in this model; a household, a retailer, and a bottlemaker.

First of all, we illustrate the structure of the model in Figure 1. A set of available time for the household is the only resource in this economy. We divide the materials cycle indicated by a set of broad arrows by two parts; Production Side and Treatment Side. All the agents participate on both sides, although the bottlemaker plays a more important role than the others do on Treatment Side. Three rhombuses outside that side show marginal (dis)utilities not intended for the household, that is, external (dis)economies.

---- Figure 1. The Materials Cycle of the Model. ----

In the following, we introduce mathematical assumptions that are applied on each side of this model.

2.1. Description of Treatment Side

We explain assumptions on Treatment Side first. The amount of beverage in a bottle, namely that of "consumption good," is represented by C. It is assumed to be equal to the number of bottle (namely, one unit of beverage is contained in a bottle). After consuming beverages, the household has two choices associated with the empty bottles; to return them to a retailer who succeedingly returns them to a bottlemaker, or to dump them (illegally) without any private cost. The amounts of empty bottle returned and dumped are represented by R and D, respectively. A materials balance condition after consumption of the beverages is assumed to be held as

$$C = R + D. \tag{2-1}$$

The returned bottles are ultimately designated to the bottlemaker via the retailer. The bottlemaker separates and cleans them using labor to recover cullets, K, which can be used for the next production of bottles. The remaining parts are called wastes, W, which in turn are disposed by landfilling.

The amount of cullet is defined as

$$K \equiv \phi\left(X^{S}\right)R, \tag{2-2}$$

where $\phi\left(X^{S}\right) \in [0,1)$ is "the recovering rate" using labor X^{S} to recover (separate and clean, for example) the bottles returned, and is assumed to be strictly increasing and concave with respect to the labor, $\phi' > 0$ and $\phi'' < 0$. It is also assumed that the rate is zero without labor, $\phi(0) = 0$. On the other hand, the amount of waste is defined as

$$W \equiv \left(1 - \phi\left(X^{S}\right)\right)R. \tag{2-3}$$

The total amount of bottle returned must be the sum of the amount of cullet and that of waste, as indicated by equations (2-2) and (2-3).

2.2. Description of Production Side

There are two types of output on Production Side; a bottle and a beverage. The former is produced using labor and cullets which are employed from the household and a recovering process by the bottlemaker, respectively. Any materials input other than the cullet is suppressed for simplification. The amount of bottle is defined as

$$B \equiv G\left(X^{B}, K\right), \tag{2-4}$$

where X^{B} and K are the amounts of labor and cullet, respectively. The function above is assumed to be continuous, twice differentiable, strictly increasing and concave with respect to each input, namely,

$$G_{X} > 0, \quad G_{K} > 0, \quad G_{XX} < 0 \quad \text{and} \quad G_{KK} < 0. \tag{2-5}$$

For simplicity, the cross derivative is assumed to be zero $\left(G_{XK} = 0\right)$.

As the second output, a beverage (consumption good) is produced using labor and bottles which are employed from the household and the bottlemaker, respectively. Any materials input other than the bottle is suppressed. The amount of beverage is defined as

$$C \equiv F\left(X^{C}, B\right), \tag{2-6}$$

where X^{C} and B are the amounts of labor and bottle, respectively. This function is also assumed to be continuous, twice differentiable, strictly increasing and concave with respect to each input, namely,

$$F_X > 0, \quad F_B > 0, \quad F_{XX} < 0 \quad \text{and} \quad F_{BB} < 0. \tag{2-7}$$

And the cross derivative is assumed to be zero $(F_{XB} = 0)$.

2.3. Utility Function and Resource Constraint

The utility function of the household is defined as

$$\begin{aligned} U &\equiv U\left[C, X^L, R, D, W, K\right] \\ &= U\left[C, X^L, R, D, \left(1-\phi\left(X^S\right)\right)R, \phi\left(X^S\right)R\right], \end{aligned} \tag{2-8}$$

where

$$U_C > 0, \quad U_X > 0, \quad U_R < 0, \quad U_D < 0, \quad U_W < 0 \quad \text{and} \quad U_K > 0. \tag{2-9}$$

X^L is the amount of leisure for the household. Both consumption of beverages and leisure increase the utility, whereas returning the empty bottles decreases it for several troublesome treatments (washing them in water and keeping for a while, for example).

Furthermore, both dumping of the bottles after consumption and disposing of wastes decrease the utility of the household, while the use of cullets in production increases it. We assume that the household cannot recognize the extent and the effect of these activities (even for dumping) on his/her utility, so these yield external benefits and/or costs to him/her.

Finally, the resource constraint closes the model, represented by

$$\overline{X} = X^C + X^B + X^S + X^L. \tag{2-10}$$

$\overline{X}$ is the total amount of time available for the household.

3. Pareto Optimum Conditions

A social planner solves an optimization problem that is to maximize

$$U\left[C, X^L, R, D, \left(1-\phi\left(X^S\right)\right)R, \phi\left(X^S\right)R\right], \tag{3-1}$$

subject to

$$\begin{aligned} &C = F\left(X^C, B\right), \quad B = G\left(X^B, K\right), \quad K = \phi\left(X^S\right)R, \\ &C = R + D \quad \text{and} \quad \overline{X} = X^C + X^B + X^S + X^L. \end{aligned} \tag{3-2}$$

The corresponding Lagrangean is set to be

$$\Lambda \equiv U\left[C, X^L, R, D, \left(1-\phi\left(X^S\right)\right)R, \phi\left(X^S\right)R\right]$$

$$+\lambda\left[F\left(X^C, B\right)-C\right]+\mu\left[G\left(X^B, K\right)-B\right]+\eta\left[\phi\left(X^S\right)R-K\right] \tag{3-3}$$

$$+\kappa\left[C-R-D\right]+\sigma\left[\overline{X}-X^C-X^B-X^S-X^L\right],$$

where λ, μ, η, κ, and σ are the Lagrangean multipliers associated with each constraint. The first-order conditions for Pareto optimum allocation are obtained as follows (where interior solutions and the equality of each constraint are all assumed, and the second-order conditions are to be satisfied).

$$U_C + U_D = \lambda, \tag{3-4}$$

$$U_X = \sigma, \tag{3-5}$$

$$-\eta\phi = U_R - U_D + (1-\phi)U_W + \phi U_K, \tag{3-6}$$

$$U_D = \kappa, \tag{3-7}$$

$$\eta\phi' R = \sigma + \phi' R\left(U_W - U_K\right), \tag{3-8}$$

$$F_X = \frac{\sigma}{\lambda}, \tag{3-9}$$

$$F_B = \frac{\mu}{\lambda}, \tag{3-10}$$

$$G_X = \frac{\sigma}{\mu}, \quad \text{and} \tag{3-11}$$

$$G_K = \frac{\eta}{\mu}. \tag{3-12}$$

4. Competitive Equilibrium Conditions

In this section, we derive competitive equilibrium conditions from decentralized decision-making by each economic agent.

First, the household is assumed to maximize his/her utility

$$U \equiv U\left[C, X^L, R, \overline{D}, \overline{W}, \overline{K}\right], \tag{4-1}$$

subject to the materials balance condition after consumption of the beverages (Equation (2-1)), and the budget constraint

$$P^X\left(\overline{X}-X^L\right) = \left(P^C + T^C\right)C + T^D D - P^2 R. \tag{4-2}$$

The variables with the upper bar in the utility function (4-1) denote the ones that he/she does not take into account. Hence, these have no effect on his/her decision-making.

In Equation (4-2), P^X and P^C are the prices per unit of labor (or leisure) and beverage, respectively. P^2 is the reward per unit of empty bottle paid by the retailer. T^C and T^D are the tax rates of beverage purchased and bottle dumped, respectively. The household solves this constrained utility-maximizing problem by setting the Lagrangean,

$$\begin{aligned}\Lambda^c \equiv & U\left[C, X^L, R, \overline{D}, \overline{W}, \overline{K}\right] \\ & + \kappa^c\left[C - R - D\right] + \sigma^c\left[P^X \overline{X} - P^X X^L - \left(P^C + T^C\right)C - T^D D + P^2 R\right],\end{aligned} \tag{4-3}$$

where the Lagrangean multipliers with the superscript c denote the ones in competitive markets hereafter. The first-order conditions are,

$$U_C = \sigma^c T^D + \sigma^c\left(P^C + T^C\right), \tag{4-4}$$

$$U_X = \sigma^c P^X, \tag{4-5}$$

$$U_R = -\sigma^c T^D - \sigma^c P^2, \quad \text{and} \tag{4-6}$$

$$\kappa^c = -\sigma^c T^D. \tag{4-7}$$

Second, the retailer maximizes his/her profits defined as a constrained profits function,

$$\Pi^R \equiv P^C C - \left(P^X + T^{XC}\right)X^C - \left(P^B + T^B\right)B + P^1 R - \left(P^2 + T^2\right)R + \lambda^c\left[F\left(X^C, B\right) - C\right]. \tag{4-8}$$

P^B is the price per unit of bottle. P^1 is the reward per unit of empty bottle paid by the bottlemaker. T^{XC}, T^B and T^2 are the tax rates of labor, bottle newly purchased and empty bottle from the household, respectively. The first-order conditions for this maximization are,

$$P^C = \lambda^c, \tag{4-9}$$

$$F_X = \frac{P^X + T^{XC}}{\lambda^c}, \tag{4-10}$$

$$F_B = \frac{P^B + T^B}{\lambda^c}, \quad \text{and} \tag{4-11}$$

$$P^1 = P^2 + T^2. \tag{4-12}$$

Finally, the bottlemaker maximizes his/her profits defined as a constrained profits function,

$$\Pi^B \equiv P^B B - \left(P^X + T^{XB}\right)X^B - \left(P^1 + T^1\right)R - \left(P^X + T^{XS}\right)X^S$$
$$- \left(1-\phi\left(X^S\right)\right)R \cdot T^W - \phi\left(X^S\right)R \cdot T^K \tag{4-13}$$
$$+ \mu^c\left[G\left(X^B, K\right) - B\right] + \eta^c\left[\phi\left(X^S\right)R - K\right]$$

T^{XB}, T^1 and T^{XS} are the tax rates of labor for producing bottles, empty bottle from the retailer, and labor for recovering the empty bottles, respectively. Also, T^W and T^K are the tax rates of waste and cullet, respectively. The first-order conditions for this maximization are,

$$P^B = \mu^c, \tag{4-14}$$
$$G_X = \frac{P^X + T^{XB}}{\mu^c}, \tag{4-15}$$
$$\eta^c \phi = P^1 + T^1 + (1-\phi)T^W + \phi T^K, \tag{4-16}$$
$$\eta^c \phi' R = P^X + T^{XS} - \phi' R\left(T^W - T^K\right), \quad \text{and} \tag{4-17}$$
$$G_K = \frac{\eta^c}{\mu^c}. \tag{4-18}$$

5. Derivation of Tax-and-Subsidy Equations

In this section, we compare the Pareto optimum conditions (in section 3) and the competitive equilibrium conditions (in section 4), and then derive equations to determine tax and/or subsidy rates for internalizing the externalities in this model.

First of all, the price per unit of labor is easily obtained from equations (3-5) and (4-5),

$$P^X = \frac{\sigma}{\sigma^c}. \tag{5-1}$$

From equations (3-4), (4-4) and (4-9),

$$\sigma^c \lambda^c + \sigma^c\left(T^D + T^C\right) = \lambda - U_D. \tag{5-2}$$

From equations (3-6), (4-6), (4-12) and (4-16),

$$\sigma^c\left[\eta^c \phi - T^1 - (1-\phi)T^W - \phi T^K - T^2\right] + \sigma^c T^D = \eta\phi - U_D + (1-\phi)U_W + \phi U_K. \tag{5-3}$$

From equations (3-8), (4-17) and (5-1),

$$\frac{\dfrac{\sigma}{\sigma^c}+T^{XS}-\phi' R\left(T^W-T^K\right)}{\eta^c}=\frac{\sigma+\phi' R\left(U_W-U_K\right)}{\eta}. \tag{5-4}$$

On the other hand, equating (3-9) to (4-10), (3-10) to (4-11), (3-11) to (4-15) and (3-12) to (4-18), using (4-14) and (5-1), we obtain four equations as follows.

$$\lambda^c=\lambda\left(\frac{1}{\sigma^c}+\frac{T^{XC}}{\sigma}\right), \tag{5-5}$$

$$\mu^c=\mu\left(\frac{1}{\sigma^c}+\frac{T^{XB}}{\sigma}\right), \tag{5-6}$$

$$\eta^c=\eta\left(\frac{1}{\sigma^c}+\frac{T^{XB}}{\sigma}\right), \quad \text{and} \tag{5-7}$$

$$T^B=\frac{\mu}{\sigma}\left(T^{XC}-T^{XB}\right). \tag{5-8}$$

As a result, we derive the following three important equations (as well as Equation (5-8)) to determine what type of tax and/or subsidy must be required to internalize externalities.

$$T^D+T^C+\frac{1}{F_X}T^{XC}=-\frac{U_D}{\sigma^c}, \tag{5-9}$$

$$-T^D+(1-\phi)T^W+\phi T^K+T^1+T^2-\phi\frac{\eta}{\sigma}T^{XB}=\frac{U_D}{\sigma^c}+J, \quad \text{and} \tag{5-10}$$

$$\frac{T^{XS}}{\phi' R}-T^W+T^K-\frac{\eta}{\sigma}T^{XB}=\frac{U_W-U_K}{\sigma^c}, \tag{5-11}$$

where

$$J\equiv-(1-\phi)\frac{U_W}{\sigma^c}-\phi\frac{U_K}{\sigma^c}\underset{<}{\geq}0. \tag{5-12}$$

Equation (5-12) represents the (absolute) monetary values of the marginal utility associated with wastes and cullets, weighted with each rate of contribution (the disposal and recovering rate, respectively). From the assumption (2-9), the first term on RHS of Equation (5-12) is positive, while the second one is negative. Therefore, *J* tends to be positive as the marginal disutility with disposal of wastes becomes larger, or the recovering rate becomes smaller.

Equation (5-9) states that one of the three taxes is only required to keep the equality. The

RHS of this equation is the monetary value of dumping empty bottles that turns to positive with reversing the sign. Table 1 represents each tax rate associated with dumping by the household. The taxes on the bottle dumped (marked by Type-D) and the one purchased (Type-C) are equivalent. Even without these, the tax on labor for producing the bottles could play the same role (Type-X^C) though its rate is slightly complicated by multiplying the marginal product term, F_X.

---- Table 1. Three Types of Taxation Coping with Household's Dumping. ----

Equations (5-10), (5-11) and (5-8) yield nine combinations for each type mentioned above (27 in all), represented by Table 2 (Type-D), Table 3 (Type-C) and Table 4 (Type-X^C). The name of the combination within each type is derived from its tax bases in order. Note that two taxes per unit of bottle returned are treated simply as the sum of them, T^1+T^2.

---- Table 2. Combinations of Tax-and-Subsidy in Type-D. ----

---- Table 3. Combinations of Tax-and-Subsidy in Type-C. ----

---- Table 4. Combinations of Tax-and-Subsidy in Type-X^C. ----

Briefly, we point out six important facts by observing these tables. For simplicity of explanation, the facts described below do not count any tax shown in Table 1.

[Fact-1] The minimum number of taxes and/or subsidies required in each combination is two (beside one in Table 1), and we find the twelve combinations that satisfy this requirement; six in Type-D (D-WK, D-WR, D-WX^S, D-KR, D-KX^S, and D-RX^S), six in Type-C (C-WK, C-WR, C-WX^S, C-KR, C-KX^S, and C-RX^S), and zero in Type-X^C.

[Fact-2] Within [Fact-1], the four combinations of *definite* one tax and one subsidy exist; three in Type-D (D-WK, D-WR, and D-KR), and one in Type-C (C-WR). In particular, the returned bottles are *taxed* (and the cullets are subsidized) in D-KR.

[Fact-3] If J in Equation (5-12) is positive at the Pareto optimum, three combinations consequently consist of one tax and one subsidy; D-WX^S, D-KX^S, and D-RX^S. In all cases, using labor for recovering cullets is subsidized.

[Fact-4] If $|U_D| > |U_W|$ at the Pareto optimum, combinations of C-WK and C-KR are composed of subsidies only.

[Fact-5] The subsidy to the bottle purchased must be combined with the tax on labor producing it; D-WX^{B}B, D-RX^{B}B, C-WX^{B}B, and C-RX^{B}B. However, in Type-X^C, it is not clear whether the bottles are subsidized or not when the tax on labor is required (X^C-WX^{B}B and X^C-RX^{B}B), since labor producing beverages is also taxed, as in Equation (5-8).

[Fact-6] The tax-and-subsidy combination in C-KR is solely related to the materials cycle shown in Figure 1, which has some persuasiveness to make a target of such circulated materials and implement the proper policies on them. The beverages on sale are taxed, whereas the returned ones are subsidized if $|U_D| > |U_W|$. The cullets are also subsidized.

6. Tax-and-Subsidy Sharing Rules

Using the results derived in the previous section, we propose tax-and-subsidy sharing rules that have three characteristics; (i) assigned to two agents out of three, (ii) imposing a definite tax burden on each agent among (i), and (iii) setting the taxes and subsidies separately to one agent on Production Side and another on Treatment Side. These rules are practically useful since a policy maker may reduce some difficulties related to the policy administration as the number of agent becomes smaller. It is also convenient for the agents to recognize whether taxes or subsidies are required, and on which side they are taxed or subsidized.

6.1. Sharing Rules Assigned to Two Agents

Two types of tax-and-subsidy sharing rules are arranged in Table 5 and 6. The former involves a household and a bottlemaker (Rule-hb), and the latter does a retailer and a bottlemaker (Rule-rb). There is no combination with a household and a retailer, however.

---- Table 5. Tax-and-Subsidy Sharing Rules [hb]: Household and Bottlemaker. ----

---- Table 6. Tax-and-Subsidy Sharing Rules [rb]: Retailer and Bottlemaker. ----

Rule-hb has twelve patterns of tax-and-subsidy combinations, while Rule-rb has thirteen ones. Superscripts on signs at each PER UNIT column denote objects of taxation or subsidization. For simplicity, we assume that the functions *B* and *C* (defined as equations (2-4) and (2-6)) are linear homogenous at the Pareto optimum in calculating the net tax burden on each agent.

6.2. Sharing Rules that Impose a Definite Tax Burden on Each Agent

Among the types in Table 5 and 6, we find combinations of tax-and-subsidy which yield definite taxation or subsidization for each agent. Table 7 shows three rules of taxation, where the household is taxed in all the cases and the bottlemaker is also taxed if J is positive.

---- Table 7. Sharing Rules that Impose Taxes on Both Agents. ----

In contrast, Table 8 shows six rules of taxation and subsidization. The household and the retailer are always taxed except Rule-rb12 on condition that J is positive. On the other hand, the bottlemaker is no doubt subsidized in Rule-rb7 and rb12, and is also in the other cases if the marginal disutility due to illegal disposal is larger than the one due to disposal of wastes. Interestingly, a unique unconditional tax-and-subsidy set can be found in Rule-rb7.

---- Table 8. Sharing Rules that Impose Taxes and Subsidies on Each Agent. ----

6.3. Sharing Rules for One Agent on One Side

Table 9 describes twelve combinations whose taxes and subsidies are set upon one agent on Production Side and another on Treatment Side. This way of classification is quite useful since we can see the policies for two agents much simply than before. The household and the retailer are involved in Production Side only, while the bottlemaker is in Treatment Side only.

---- Table 9. Sharing Rules Applied to Production/Treatment Sides. ----

As we see in Table 9, the four cases with the remarks constitute combinations of "taxes on one agent on Production Side and subsidies to another agent on Treatment Side." In Rule-hb7 and hb10, the household is taxed and the bottlemaker is subsidized. On the other hand, in Rule-rb1 and rb6, the retailer is taxed and the bottlemaker is still subsidized. Hence, it is possibly recognized that, as a whole, Production Side should be taxed and Treatment Side should be subsidized if we have to make the policies much clear.

We conclude that, by looking them carefully, the four cases are composed of any combinations of two taxed objects (*C* and X^C-*B*) and two subsidized objects (*W*-*K* and *K*-*R*), as shown in Figure 2. This fact provides further flexibility for choosing the appropriate policies among the candidates. For example, on Production Side, when the tax on the consumption good (beverage) cannot be applied for some reason, the taxes on the labor producing it and the bottle are effective as the alternatives. Similarly, on Treatment Side, when the amount of waste is hard to be observed and the amount of empty bottle returned is easier than that, the subsidy set of *K*-*R* should be chosen by the policy maker, rather than the one of *W*-*K*.

---- Figure 2. Combinations of Four Policies. ----

7. Conclusions

This paper has analyzed a general equilibrium model which takes a “materials cycle” into account, and then proposed several “tax-and-subsidy sharing rules” composed of taxes and subsidies on economic agents. Three representative agents have been assumed, a household, a retailer, and a bottlemaker. Also, three types of externality have been incorporated into the model in the form of yielding unintended marginal (dis)utility to the household where taxes and/or subsidies have been required to internalized them.

Although the materials cycle we have mentioned might be quite simple, the number of combinations of taxes and subsidies has amounted to twenty-seven. Sharing rules in this analysis have meant to be the tax-and-subsidy combinations that are assigned to any two agents out of three, and we have found three rules to impose taxes on both, and six ones to impose taxes on one agent and subsidies on another. Consequently, we have found that there are four clear rules set upon one agent on Production Side and another on Treatment Side. It is interesting that these rules consist of the common components one another, so that the policy maker can design and coordinate such policies more flexibly than in other rules.

As this analysis shows, the policies for internalizing externalities could be highly rich when the materials cycle (or recycling) is taken into account. Among them, we can choose the best policy combination suitable for each situation by comparing the potential policies with some criteria. In this paper, we focus on the (fewer) number of economic agents, the sign of each tax burden, and the specialization to each side with one agent. Of course, there could be other points of view for policy evaluation, as developed in Koide (2001). The ways of characterizing alternative policies should be sophisticated further.

On the other hand, it is important to provide theoretical models that contain more real and specific factors associated with the materials cycles, such as the multiple uses or delivered routes of recycled materials, and the difficulties in trading them among agents. As the forms of recycling vary, the policies required will be richer and more complex. Also in this situation, some criteria must be needed to arrange them in theoretical and practical manners.

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Appendix

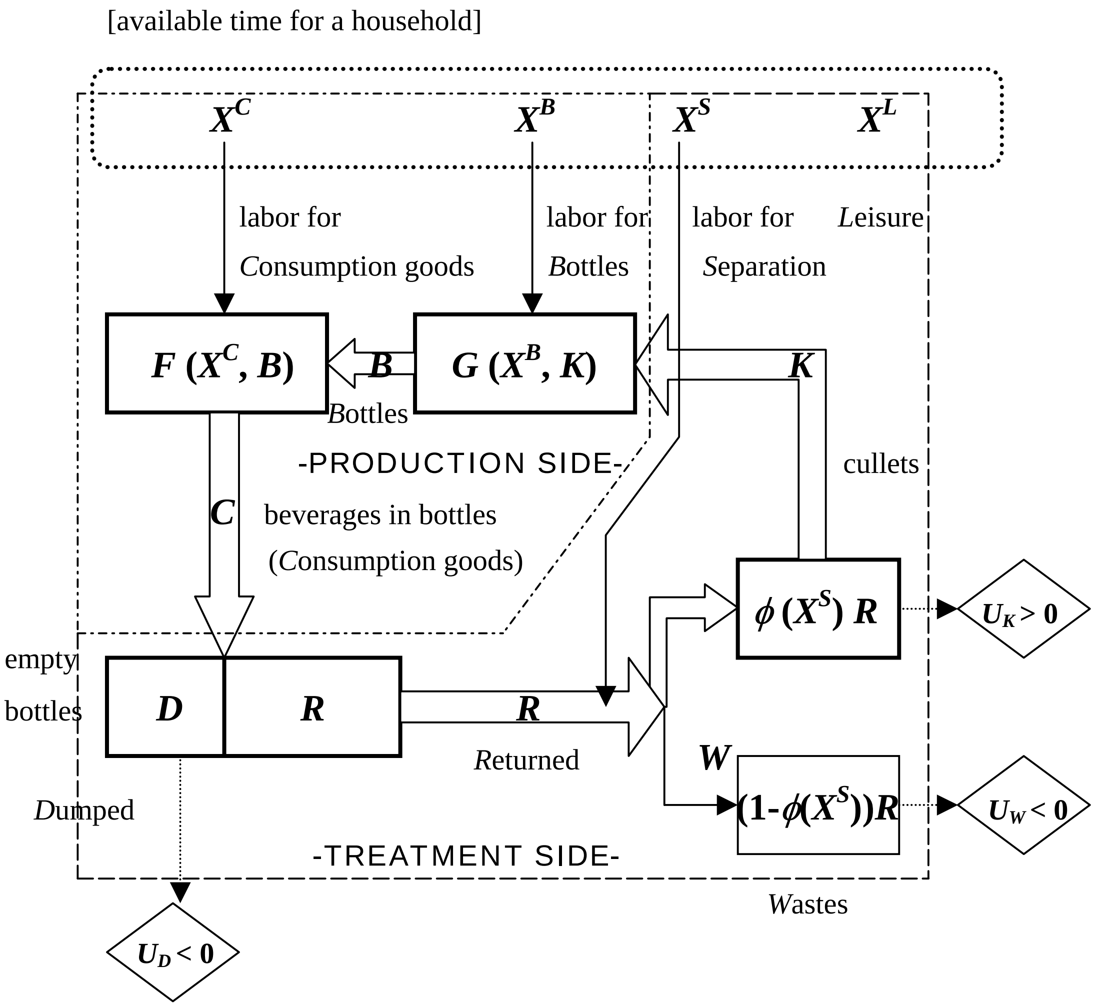


FIGURE 1. THE MATERIALS CYCLE OF THE MODEL.

Table 1. Three Types of Taxation Coping with Household's Dumping.

	TYPE-D	Type-C	Type-X^C
T^D	$-(U_D/\sigma^c) > 0$	0	0
T^C	0	$-(U_D/\sigma^c) > 0$	0
T^{XC}	0	0	$-F_X(U_D/\sigma^c) > 0$

Table 2. Combinations of Tax-and-Subsidy in Type-D.

	D-WK	D-WR	D-WX^B^B	D-WX^S^
T^W	$-(U_W/\sigma^c) > 0$	$(U_K - U_W)/\sigma^c > 0$	$-(U_W/\sigma^c) > 0$	$J/(1-\phi) > 0$ if $J > 0$
T^K	$-(U_K/\sigma^c) < 0$	0	0	0
T^1+T^2	0	$-(U_K/\sigma^c) < 0$	0	0
T^{XB}	0	0	$(G_X/G_K)(U_K/\sigma^c) > 0$	0
T^B	0	0	$(-1/G_K)(U_K/\sigma^c) < 0$	0
T^{XS}	0	0	0	$-[\phi' R/(1-\phi)](U_K/\sigma^c) < 0$

	D-KR	D-KX^S	D-RX^{B}B	D-RX^S	D-X^{B}BX^S
T^W	0	0	0	0	0
T^K	$(U_W - U_K)/\sigma^c < 0$	$J/\phi > 0$ if $J > 0$	0	0	0
T^1+T^2	$-(U_W/\sigma^c) > 0$	0	$-(U_W/\sigma^c) > 0$	J	0
T^{XB}	0	0	$(G_X/G_K)[(U_K - U_W)/\sigma^c] > 0$	0	$-(G_X/G_K)(J/\phi) < 0$ if $J > 0$
T^B	0	0	$(1/G_K)[(U_W - U_K)/\sigma^c] < 0$	0	$(1/G_K)(J/\phi) > 0$ if $J > 0$
T^{XS}	0	$(\phi' R/\phi)(U_W/\sigma^c) < 0$	0	$\phi' R(U_W - U_K)/\sigma^c < 0$	$(\phi' R/\phi)(U_W/\sigma^c) < 0$

Table 3. Combinations of Tax-and-Subsidy in Type-C.

	C-WK	C-WR	C-WX^{B}B	C-WX^S
T^W	$(U_D - U_W)/\sigma^c < 0$ if $\lvert U_D \rvert > \lvert U_W \rvert$	$(U_K - U_W)/\sigma^c > 0$	$(U_D - U_W)/\sigma^c < 0$ if $\lvert U_D \rvert > \lvert U_W \rvert$	$[(U_D/\sigma^c) + J]/(1-\phi)$
T^K	$(U_D - U_K)/\sigma^c < 0$	0	0	0
$T^1 + T^2$	0	$(U_D - U_K)/\sigma^c < 0$	0	0
T^{XB}	0	0	$(G_X/G_K)[(U_K - U_D)/\sigma^c] > 0$	0
T^B	0	0	$(1/G_K)[(U_D - U_K)/\sigma^c] < 0$	0
T^{XS}	0	0	0	$[\phi' R/(1-\phi)][(U_D - U_K)/\sigma^c] < 0$

	C-KR	C-KX^S	C-RX^{B}B	C-RX^S	C-X^{B}BX^S
T^W	0	0	0	0	0
T^K	$(U_W - U_K)/\sigma^c < 0$	$[(U_D/\sigma^c) + J]/\phi$	0	0	0
$T^1 + T^2$	$(U_D - U_W)/\sigma^c < 0$ if $\lvert U_D \rvert > \lvert U_W \rvert$	0	$(U_D - U_W)/\sigma^c < 0$ if $\lvert U_D \rvert > \lvert U_W \rvert$	$(U_D/\sigma^c) + J$	0
T^{XB}	0	0	$(G_X/G_K)[(U_K - U_W)/\sigma^c] > 0$	0	$-(G_X/G_K)[(U_D/\sigma^c) + J]/\phi$
T^B	0	0	$(1/G_K)[(U_W - U_K)/\sigma^c] < 0$	0	$(1/G_K)[(U_D/\sigma^c) + J]/\phi$
T^{XS}	0	$(\phi' R/\phi)[(U_W - U_D)/\sigma^c] > 0$ if $\lvert U_D \rvert > \lvert U_W \rvert$	0	$\phi' R(U_W - U_K)/\sigma^c < 0$	$(\phi' R/\phi)[(U_W - U_D)/\sigma^c] > 0$ if $\lvert U_D \rvert > \lvert U_W \rvert$

Table 4. Combinations of Tax-and-Subsidy in Type-X^C.

	X^C-WKB	X^C-WRB	X^C-WX^BB	X^C-WBX^S
T^W	$(U_D - U_W)/\sigma^c < 0$ if $\lvert U_D\rvert > \lvert U_W\rvert$	$(U_K - U_W)/\sigma^c > 0$	$(U_D - U_W)/\sigma^c < 0$ if $\lvert U_D\rvert > \lvert U_W\rvert$	$[(U_D/\sigma^c) + J]/(1-\phi)$
T^K	$(U_D - U_K)/\sigma^c < 0$	0	0	0
T^1+T^2	0	$(U_D - U_K)/\sigma^c < 0$	0	0
T^{XB}	0	0	$(G_X/G_K)[(U_K - U_D)/\sigma^c] > 0$	0
T^B	$-F_B(U_D/\sigma^c) > 0$	$-F_B(U_D/\sigma^c) > 0$	$-F_B(U_D/\sigma^c) + (1/G_K)[(U_D - U_K)/\sigma^c]$	$-F_B(U_D/\sigma^c) > 0$
T^{XS}	0	0	0	$[\phi' R/(1-\phi)][(U_D - U_K)/\sigma^c] < 0$

	X^C-KRB	X^C-KBX^S	X^C-RX^BB	X^C-RBX^S	X^C-X^BBX^S
T^W	0	0	0	0	0
T^K	$(U_W - U_K)/\sigma^c < 0$	$[(U_D/\sigma^c) + J]/\phi$	0	0	0
T^1+T^2	$(U_D - U_W)/\sigma^c < 0$ if $\lvert U_D\rvert > \lvert U_W\rvert$	0	$(U_D - U_W)/\sigma^c < 0$ if $\lvert U_D\rvert > \lvert U_W\rvert$	$(U_D/\sigma^c) + J$	0
T^{XB}	0	0	$(G_X/G_K)[(U_K - U_W)/\sigma^c] > 0$	0	$-(G_X/G_K)[(U_D/\sigma^c) + J]/\phi$
T^B	$-F_B(U_D/\sigma^c) > 0$	$-F_B(U_D/\sigma^c) > 0$	$-F_B(U_D/\sigma^c) + (1/G_K)[(U_W - U_K)/\sigma^c]$	$-F_B(U_D/\sigma^c) > 0$	$-F_B(U_D/\sigma^c) + (1/G_K)[(U_D/\sigma^c) + J]/\phi$
T^{XS}	0	$(\phi' R/\phi)[(U_W - U_D)/\sigma^c] > 0$ if $\lvert U_D\rvert > \lvert U_W\rvert$	0	$\phi' R(U_W - U_K)/\sigma^c < 0$	$(\phi' R/\phi)[(U_W - U_D)/\sigma^c] > 0$ if $\lvert U_D\rvert > \lvert U_W\rvert$

Table 5. Tax-and-Subsidy Sharing Rules [hb]: Household and Bottlemaker.

	TYPE	PER UNIT		TOTAL	
		household	bottlemaker	household	bottlemaker
hb1	D-WK	$+^{D}$	$+^{W}$ $-^{K}$	+	*
hb2	D-WR	$+^{D}$	$+^{W}$ $-^{R}$	+	*
hb3	D-WX^{S}	$+^{D}$	$\ast^{W}$ $-^{XS}$	+	±
hb4	D-KR	$+^{D}$	$-^{K}$ $+^{R}$	+	*
hb5	D-KX^{S}	$+^{D}$	$\ast^{K}$ $-^{XS}$	+	±
hb6	D-RX^{S}	$+^{D}$	$\ast^{R}$ $-^{XS}$	+	±
hb7	C-WK	$+^{C}$	$\div^{W}$ $-^{K}$	+	÷
hb8	C-WR	$+^{C}$	$+^{W}$ $-^{R}$	+	±
hb9	C-WX^{S}	$+^{C}$	$\pm^{W}$ $-^{XS}$	+	±
hb10	C-KR	$+^{C}$	$-^{K}$ $\div^{R}$	+	÷
hb11	C-KX^{S}	$+^{C}$	$\pm^{K}$ $\#^{XS}$	+	±
hb12	C-RX^{S}	$+^{C}$	$\pm^{R}$ $-^{XS}$	+	±

Note: + ; positive (taxed) – ; negative (subsidized) ± ; uncertain (including zero)

* ; positive if $J > 0$ ÷ ; negative if $|U_D| > |U_W|$ # ; positive if $|U_D| > |U_W|$

Table 6. Tax-and-Subsidy Sharing Rules [rb]: Retailer and Bottlemaker.

	TYPE	PER UNIT		TOTAL	
		retailer	bottlemaker	retailer	bottlemaker
rb1	X^C-WKB	$+^{XC}$ $+^{B}$	$\div^{W}$ $-^{K}$	+	÷
rb2	X^C-WRB	$+^{XC}$ $+^{B}$	$+^{W}$ $-^{R}$	+	±
rb3	…	$+^{XC}$ $-^{R}$ $+^{B}$	$+^{W}$	±	+
rb4	X^C-WX^BB	$+^{XC}$ $\pm^{B}$	$\div^{W}$ $+^{XB}$	±	±
rb5	X^C-WBX^S	$+^{XC}$ $+^{B}$	$\pm^{W}$ $-^{XS}$	+	±
rb6	X^C-KRB	$+^{XC}$ $+^{B}$	$-^{K}$ $\div^{R}$	+	÷
rb7	…	$+^{XC}$ $\div^{R}$ $+^{B}$	$-^{K}$	+	–
rb8	X^C-KBX^S	$+^{XC}$ $+^{B}$	$\pm^{K}$ $\#^{XS}$	+	±
rb9	X^C-RX^BB	$+^{XC}$ $\pm^{B}$	$\div^{R}$ $+^{XB}$	±	±
rb10	…	$+^{XC}$ $\div^{R}$ $\pm^{B}$	$+^{XB}$	±	+
rb11	X^C-RBX^S	$+^{XC}$ $+^{B}$	$\pm^{R}$ $-^{XS}$	+	±
rb12	…	$+^{XC}$ $\pm^{R}$ $+^{B}$	$-^{XS}$	*	–
rb13	X^C-X^BBX^S	$+^{XC}$ $\pm^{B}$	$\pm^{XB}$ $\#^{XS}$	±	±

Note: + ; positive (taxed) – ; negative (subsidized) ± ; uncertain (including zero)

* ; positive if $J > 0$ ÷ ; negative if $|U_D| > |U_W|$ # ; positive if $|U_D| > |U_W|$

Table 7. Sharing Rules that Impose Taxes on Both Agents.

	TYPE	Net Tax Burden		
		household	retailer	bottlemaker
hb1	D-WK	+		*
hb2	D-WR	+		*
hb4	D-KR	+		*

Note: + ; positive * ; positive if $J > 0$

Table 8. Sharing Rules that Impose Taxes and Subsidies on Each Agent.

	TYPE	Net Tax Burden		
		household	retailer	bottlemaker
hb7	C-WK	+		÷
hb10	C-KR	+		÷
rb1	X^C-WKB		+	÷
rb6	X^C-KRB		+	÷
rb7	X^C-KRB		+	–
rb12	X^C-RBX^S		*	–

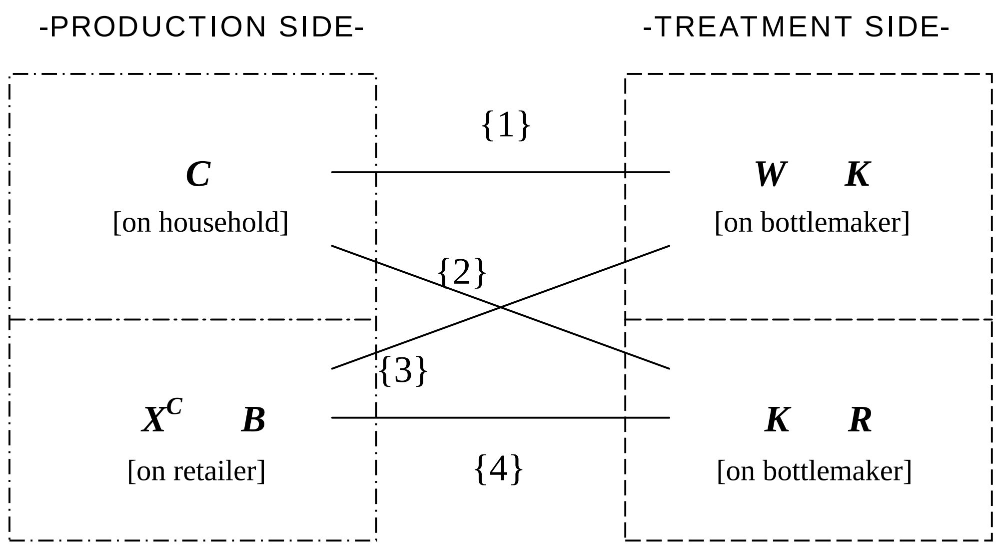
Note: + ; positive – ; negative

* ; positive if $J > 0$ ÷ ; negative if $|U_D| > |U_W|$

Table 9. Sharing Rules Applied to Production/Treatment Sides.

	TYPE	Object of Taxation			remarks (from Table 7-8)
		household (PS only)	retailer (PS only)	bottlemaker (TS only)	
hb7	C-WK	C		W K	tax & subsidy
hb8	C-WR	C		W R	
hb9	C-WX^S	C		W X^S	
hb10	C-KR	C		K R	tax & subsidy
hb11	C-KX^S	C		K X^S	
hb12	C-RX^S	C		R X^S	
rb1	X^C-WKB		X^C B	W K	tax & subsidy
rb2	X^C-WRB		X^C B	W R	
rb5	X^C-WBX^S		X^C B	W X^S	
rb6	X^C-KRB		X^C B	K R	tax & subsidy
rb8	X^C-KBX^S		X^C B	K X^S	
rb11	X^C-RBX^S		X^C B	R X^S	

Note: PS = Production Side, TS = Treatment Side.



{1} Rule-hb7 (C-WK) {2} Rule-hb10 (C-KR)
{3} Rule-rb1 (X^C-WKB) {4} Rule-rb6 (X^C-KRB)

FIGURE 2. COMBINATIONS OF FOUR POLICIES.

Recent Development in Environmental Economics Part 1

Essays on Possibilities of Wind Power

A Comparison of Sweden and Denmark

Chiho Miyamoto
Graduate School of Economics
Hitotsubashi University

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A Comparison of Sweden and Denmark

Chiho Miyamoto*

Graduate School of Economics

Hitotsubashi University

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Abstract

Wind power is generally considered to promote sustainable development in energy sector. In practice, however, its share in energy market is not so high. The first objective of this thesis is to try to find the main reasons. The focus is particularly on wind power as a component of post-nuclear option. A comparative study was carried out with Swedish and Danish cases. Sweden was selected as a country to move toward nuclear free society and Denmark as a successful country in developing wind power. One distinction between these two countries is that the former is a nuclear society while the latter is not. Still many similarities in both countries implicate that the comparison is meaningful. One key point is the importance of environment in the society. For example, one of the objectives of environmental consideration in energy policy is to reduce impact from energy sector in both countries. The second objective of this thesis is to draw lessons for Sweden from Denmark.

Executive Summary

Energy, particularly electricity, is essential for modern life. It became more and more clear, however, that it is a main source of environmental problems. Acidification and climatic change are distinctive examples caused by life cycle of energy. Current fossil based energy supply system is challenged by these major atmospheric problems. Other conventional source, i.e. nuclear power, was believed to be a saviour to solve these problems. It became clear, however, that it imposes immense cost on society. Not only it is neither free from pollution, i.e. it produces radioactive nuclear wastes but also safety concern is persistent. Therefore it is not desirable to continue to depend on conventional energy supply system in the long run.

Wind power has many possibilities to be a component for post-nuclear energy system because of its less environmental damaging characteristics. Its raw material, wind, is exhaustless and indigenous and decentralised in nature, thus contributing to regional energy security. It does not need hazardous raw material processing nor generates dangerous wastes.

In general wind power is widely accepted as an environmentally benign energy source. In practice, however, it is not much developed in the world except for few countries. Most of these countries are in Europe, which has windmill tradition and where environmental consciousness is high. Denmark is one of them and has been famous for its wind power development since 1980s. Its neighbour, Sweden, is also known for its advanced environmental policy, but with nuclear power. Although objectives in energy policy, i.e. to reduce environmental impact from energy sector, are similar in the two countries their performances are different. In 1999 the share of wind power in gross inland energy consumption is 0.8% in Denmark while it is not tenth of it in Sweden.

It is interesting to investigate the background for this distinction. Main research objective of the study is to clarify predominant drivers and barriers for wind power development through comparing the two countries. Second objective is to discuss whether Sweden can learn from the fairly successful Danish experience.

Overview of the Danish case clarified that it has important driving factors for wind power development. Among others strong and consistent governmental initiative to promote wind power is a significant factor. For Government wind power has been an important means to reach the target in energy policy. Lack of political uncertainty around wind power is basis for other crucial factors. Traditional wind co-operatives have been supported by, among others, generous state subsidies and private individual involvement in wind power development has been strengthened. Several policy instruments including spatial planning legislation are organised to support optimal use of wind energy. Danish power industry has also been involved in wind power development through active state initiative. Assurance by the Government has influenced Danish financial sector positively to create favourable climate for wind power investments. These active governmental policies were possible in

Denmark under regulated electricity market. High electricity price due to high tax is another important factor in wind power development. Currently Danish electricity market is on its way to be liberated. The Government also commits itself to be active in supporting wind energy in the coming fully deregulated market.

As wind turbine industry plays important role in Danish economy, Danish government has interest in developing wind power from national economy perspective. It is one reason that enables different political parties to agree on consistent support on wind energy. In this sense not only environmental concern has promoted Denmark towards, to some extent, a wind energy society. All of these factors worked positively to wind power development. The result is that the total installed capacity of wind turbines was around 1750 MW by the end of 1999.

Sweden has different energy policy background. First it had vigorously promoted nuclear power since 1950s, which has played an important role in the electricity supply system. And it has been a main discussion theme in Swedish energy policy since 1980s. Compared to the nuclear issue wind power is not considered as urgent point to be discussed. As current Swedish electricity supply system is based on nuclear and hydropower, which are basically carbon free, climate issue that pushed Denmark to wind power development does not work in the same way in Sweden. This situation will, however, change when nuclear power plants are closed down in the future. At the moment there is no driving force for Sweden to move to further wind power development. Nuclear issue has more or less paralysed the parliament politics and caused inconsistent energy policy.

Weak governmental initiative is a second characteristic. Building permissions have been another main obstacle in wind power installation in Sweden. As national government commitment to promote wind power has not enough strength, the reaction of the regional and local government that are in charge of issuing the permit is slow. In general the coordination between different levels of government regarding wind power is not well organised. Complicated legislations and permission procedure aggravate the situation.

Thirdly Swedish industry structure is not favourable for wind power. Nuclear industry is an established part of Swedish society and wind turbine industry is too young and small to play substantial part. In this respect there is not so much national interest to promote wind power. Cheap sufficient electricity from nuclear and hydropower is a critical factor. Power industry does not see point in investing new energy system under current situation with available cheap power and no rule for long-term investment guarantee. At the moment consumer demand on “green electricity” is an only driver to promote wind power in Sweden. Eco-labelled green electricity provided 6.8 TWh in 1999 and its quantity is expected to increase further.

It is important to note that wind power is not only option for Sweden. It has large forest resource, which can be turned into biomass. Contrary to wind turbine industry forest industry contributes substantially to the Swedish economy. Biomass related technology and products have better possibility in gaining international market. Climate issues that is a driving force for Danish wind power development, has more implication on biofuel in Sweden in that it has a substantial position in the society.

Although the background is different, Sweden may still learn several lessons from the Danish experience. First, strong governmental commitment is essential in promoting wind power. Danish government has been supporting wind power through various channels including legislation, generous subsidy scheme and control over power industry. If Sweden were to develop a wind power, reliable policy is vital but that does not necessarily mean that it has to use heavy subsidies. As Sweden has already deregulated the electricity market it is impossible to subsidise wind power as Denmark has done. The role of Government is to set non-discriminative rule for all alternative energy sources including wind energy to compete with conventional energy on the same condition. Current situation is not always favourable for new energy in terms of cost calculation.

Secondly as wind power is one of many alternatives for Sweden, it is important for the Government to assess how it can be coordinated with other energy sources and integrated into the current system. It is important to carry out consistent policy to advance further in a cost-effective way.

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1. Introduction

1.1 Background (Electricity)

Modern civilization is to a great degree dependent on energy consumption. Particularly electricity, transformed form of energy, has contributed to the modern material comfort. Rapid expansion of electricity system has enabled to supply enormous amount of electricity. At the same time energy consumption brought about inevitable negative effects, i.e. environmental problem. Energy sector has been, needless to say, one of the major sources for environmental pollution throughout its pre-production, production, consumption and some times disposal phase. Energy is indispensable for modern society but the more it is consumed to pursue material comfort the worse the accompanied problems become, i.e. more pressure on natural ecosystem. Is there any way to enjoy decently comfortable life and at the same time minimise negative impact on environment?

Today more than two billion people still do not have access to electricity. Considering increasing number of developing countries is on their way to a more industrialised society utilising larger amount of electricity, it is urgent to solve this dilemma of modern society. Based on the fact that energy consumption is essential for modern society, one of the solutions is to try to reduce environmental effect from the supply side. The concept "sustainable electricity" means that it is available to all at an affordable cost and that it does not impose unacceptable burden on the environment, locally, regionally or globally[1].

1.2 Wind power as a component of the post-nuclear option

Since its development since 1940s nuclear energy has played important role in energy supply system in modern society. Together with other fuel-fired thermal power and hydroelectric power, it has greatly supported material comfort. According to IEA, International Energy Agency, globally hydroelectric power produced 2566 terawatt-hours or TWh, fuel-fired thermal power, 8776 TWh and nuclear power 2393 TWh in 1997[2]. Throughout the past century, these large-scale power supply systems have determined the structure of world electricity system. Of all three types of conventional power, nuclear power is latecomer. It entered the world energy supply picture as alternative to fossil fuels and hydroelectricity with vigorous national and international political backing. It was enthusiastically welcomed by the modern society to be able to supply "sustainable electricity." However, it turned out that although nuclear power does not emit ordinary air pollutant such as CO_2, SO_x and NO_x like

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1 Patterson, W. (1999). *Transforming Electricity. The Coming Generation of Change*. London: Earthscan Publications, p.170.

2 Calculated from IEA. (1999). *Key World Energy Statistics from the IEA*. Paris: International Energy Agency.

conventional fossil fuel based power plant it is neither free from pollution. It has been emitting toxic and radioactive nuclear waste, which modern society has not yet found out acceptable way to manage and to dispose. Apart from this nearly insuperable problem, persistent issues are cost, liability and concern about its safety. It became apparent that from recent accident in Japan that any serious problem can occur by accident throughout its life cycle from extraction, transportation and production. There is no way to avoid accidents completely. Thus it is not feasible to expand and continue operating nuclear power plants in the long run. Reflecting that its acceptability by society is not increasing, it is preferable to search for other options that would clear the problems of nuclear energy.

This thesis will address itself to wind energy as a component of for post nuclear energy system. Wind energy has many attributes that nuclear energy lacks. First it is not depleted by use and dependent only on the sun's energy and is free. It is indigenous and decentralised in nature thus there is no environmental problem caused by raw material transportation and it can contribute to reducing dependency of energy imports of the region (security of supply). Secondly it does not require risky raw material processing thus no environmental problem is caused before energy production. Thirdly it does not produce hazardous waste by energy production. Reflecting that electricity is necessary for modern civilization and it is urgent to find "sustainable electricity," wind energy with its less environmental damaging impact compared to nuclear energy seems a promising alternative.

1.3 Objective and Research Questions

In spite of the benefits wind energy does not seem to be successful in penetrating the market. There are few exceptions. In Europe it is Germany, Denmark, U.K. and Netherlands. In North America, California is well known as a state supported by electricity generated from large wind farms.

Reflecting urgent need for development of alternative to nuclear energy this thesis will investigate the possibility of wind power. For this purpose the thesis will try to clarify the reasons that wind power does not yet prevail, but also the reasons for success. Two comparable countries are chosen for this purpose. On one hand, to illustrate problems of a post-nuclear society, Sweden is selected. Sweden has not succeeded in raising the share of wind-generated electricity. On the other hand, Denmark is chosen as a counterpart successfully developing wind power.

Sweden and Denmark, neighbours in Scandinavia, are both known as environmentally conscious countries and have progressive environmental policy with strict environmental regulations. And since 1980s their objective in energy policy has been more or less similar in that it aims to reduce impact on environment from energy sector and to increase the supply share from renewable energy sources. Their effort can be indicated by the funds, which they have spent on wind power since then. The difference of renewable energy performance makes, however, high contrast. In 1999 Denmark has already achieved wind energy share of 10% of electricity consumption while Sweden has not reached tenth of it (0.25%). To investigate and clarify the reason for this difference is the main theme of this thesis.

Overall objective of this thesis is to reveal both the predominant drivers that enable wind power to gain market shares and barriers that prevent its development in these two countries. The focus is on not only macro (national) perspective but also on micro (industrial and private individual) perspective. In doing so implication for Kyoto protocol (CO_2 discussion) to wind power development will be investigated. And to discuss how the advanced Danish experiences might apply in Swedish context is another purpose.

Issues that will be addressed are: “Even though objectives of environmental consideration in energy policy being similar, why are actual performance in two countries different?” “Is it the national government initiative that makes wind power prevalent in Denmark? Or that of power industry or something else?” “How are the barriers overcome in Denmark? Is it possible for Sweden to employ the same method?” “How about the Swedish case? Is national government initiative strong enough?” “From industry perspective, how does the national government initiative affect them?”

1.4 Research Method

In order to answer research questions the following methods are employed in this thesis. First a general overview of drivers and barriers of wind power development is conducted to pinpoint important factors. Second, the Danish case was studied through national energy policy, industrial perspective and other aspects. Same approach is taken for Sweden. Finally the two cases are compared focusing on main aspects. To get reliable information on the viewpoints of different actors qualitative approach, qualitative questionnaire and interviews, have been used. This method was partly used to gather quantitative data on energy sector and the wind power development.

1.4.1 Collecting and Analysis of Primary Data

The primary data is information gathered through questionnaires and interviews. Its main purpose is to supplement lack of written information on views from different organisations around wind energy. Questionnaires and interviews were conducted to power companies, wind turbine industry, independent wind developers and government authorities in Sweden and power utility association, wind turbine association, wind turbine industry and government authorities in Denmark. The form of questionnaires is shown in the appendix.

In order to analyse comparatively information was gathered parallelly in both countries as much as possible. To get the information related the research questions, 8 questionnaires and 4 interviews were carried out between April and September 2000. In Sweden two power companies (Vattenfall AB and Sydkraft AB), two wind turbine companies (Nordic Windpower AB and SW Vindkraft), an independent wind developer and the authority participated in this research. In Denmark the power association, one wind turbine company (Nordex), the wind turbine manufacturers association and the authority participated. For the green electricity investigation, 9 companies (electricity producer/distributor) in Sweden took part.

1.4.2 Gathering and Analysis of Secondary Data

Secondary source are used to support the background information for primary data. They are energy statistics, national legislations concerning wind energy and official publications by the Governments. Some of these secondary data were directly obtained from the authorities and others were gathered through Internet. In addition, as environmental studies have interdisciplinary nature, this thesis of wind energy development analysis also needs such background. This thesis includes literature from among others natural science, wind energy technology, social science, economics and corporate environmental management. These were gathered mainly from journal articles and books.

1.5 Scope and Limitations

Except for chapter 2 with general overview of drivers and obstacles, two countries, Sweden and Denmark, are selected as case study material. Reason for the choice is their contrasting development. One limitation is that only Sweden has nuclear power. So for Denmark wind power is not post-nuclear option. Another limitation is the difference in country size, in structure of the industry and in available energy sources. Sweden has 450,000 km^2 with population of 8.9 million[3] while Denmark has 43,094 km^2 with population of 5.2 million[4]. Sweden is rich in hydropower while Denmark is not. However they are geographically close and have culturally similar background sharing similar view toward the environment and have different performance particularly in wind power development. The period covered is the time after 1980s when wind energy policy started.

One should be aware of the fact that there is a divergence in available information in these two countries. While Denmark has had intensive wind energy development since 1980s and has already gained good results and information and knowledge are accumulated, Sweden has just started to increase the number of installed turbines in the beginning of 1990s. Therefore, experience and available information are rather limited in Sweden. To overcome this limitation intensive interviews were carried out to Swedish organisation.

It should be also noted that in this thesis wind power is not seen as a substitute to nuclear power. It is

[3] Statistics Sweden. (2000). http://www.scb.se/indexeng.htm [2000, September 9].

[4] Statistics Denmark. (2000). http://www.dst.dk:80/siab.asp?o_id=665 [2000, September 9].

not realistic to substitute base load (nuclear) with peak load (wind). It is already mentioned that at the moment wind power can provide at maximum 20% of total energy supply[5]. Instead it is considered as one of the important elements in current energy supply system. Thus ultimate research questions in this thesis are to indicate how wind power can be incorporated into current energy system as a limited but still important element.

1.6 Thesis Outline

This thesis is structured as follows. The following chapter describes basic facts and backgrounds of wind power. It includes worldwide status, brief history, technology description and positive as well as negative aspects of wind power. Chapter 3 overviews drivers and barriers for wind power development in general. This analysis will be referred to in following chapters.

Chapter 4 and 5 are dedicated to Danish and Swedish case study respectively. Both chapters start with general overview of energy supply and end with final remarks. They are separated into sections with regard to significant factors affecting wind power development. In Danish case they are national government commitment (4.2), effective policy instruments related to wind power (4.3), business growth in wind turbine industry and power industry (4.4) and Wind co-operatives and individual turbine ownership development (4.5).

In chapter 5, in the Swedish case, different factors are identified as significant. They are related legislations (5.2), recent national government initiative and commitment (5.3), rather weak policy instrument around wind energy (5.4), slow wind turbine industry development (5.5) and independent wind developer's perspective (5.6). The last factor turned out to be as important as the counterpart in Denmark.

In the next chapter, comparison of these two countries is carried out. The purpose of the synthesis is to derive dissimilarity and resemblance to illuminate main drivers and barriers for wind power development. It starts with review of two countries (6.1 and 6.2). In the third section six different levels are compared: legislation (6.2.1), national government commitment (6.2.2), supporting instrument (6.2.3), energy sector (6.2.4), industry perspective (6.2.5), consumer perspective (6.2.6) and others (6.2.7). The chapter ends with brief concluding comments.

Through reflecting the facts found in previous chapters, chapter 7 will make discussions on main issues around wind power. They are: SWOT analysis of wind power (7.1), climate change issue implications for wind power (7.2), the approach from supply-side focusing on various social costs of electricity generations (7.3), the current trend in demand-side, i.e. green electricity issue (7.4) and examine the

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5 Street, P. & Miles I. (1996). Transition to alternative energy supply technologies. *Journal of Energy Policy*, 24, 5, 420.

possibility of wind power development in Sweden including lessons to learn from Denmark (7.5). Finally conclusions and recommendations are given in chapter 8.

2. Introduction to Wind Power

Global production of wind-generated electricity has risen from practically zero in the early 1980s to 21.8 TWh in 1999. The amounts of each part of the world are: North America, 4.4 TWh (20%), Europe, 14.9 TWh (68%) and Asia, 2.3 TWh (11%)[6].

Brief history of wind power

The origin of wind turbine is horizontal-axis windmills invented in Persia A.D. 644. Then they were used for grinding grains. Vertical-axis windmill was developed in Europe in 12th century. In addition to grinding grains its usage was draining lowland areas and water pumping[7]. Windmill liberated people from toil of grinding grain by hand and thus was seen as an instrument of social progress[8]. It also served as vehicles to rebel against feudal tyranny in the medieval society. Contrary to watermills which were controlled by feudal lord, windmills were more freely utilised[9]. In later times windmill had been main power for small-scale industrial process such as paper works and the sawmill yards until large-scale steam engine, steam and gas turbines and oil and gas based engines took over its position in the industrial revolution.

Description of Technology

A wind turbine harvests power input by converting the force of wind into torque (turning force) acting on the rotor blades. This operation is known as aerodynamics of wind turbines.

The basic aerodynamic principles of a horizontal axis wind turbine are illustrated in the Figure A-1 in appendix. When the wind passes over top and bottom surfaces of the airfoil shaped blade, because of the airfoil shape it passes more rapidly over the longer (upper) side of the blade. This generates a lower-pressure area on top. The pressure differential between upper and lower surfaces creates a force, called aerodynamic lift. As the blades of a wind turbine are fixed to move in a plane with the hub as its centre, the lift force causes their rotation around the hub. In addition to lift force, a "drag" force perpendicular to the lift force impedes rotor spinning. Each length of the blade has optimal lift-to-drag ratio to maximise turbine's energy output at various wind speeds.

The wind captured by rotor blades is transferred its power to the rotor hub. The hub is attached to the

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[6] Gipe, P. (2000, August 10). Personal communication.

[7] Energy conversion. (2000). In *Encyclopædia Britannica Online*. http://www.eb.com:180/bol/topic?idxref=367959 [2000, August 5].

[8] Stokhuyzen, F. (1962). *The Dutch Windmill*. http://www2.nhl.nl/~smits/windmill.htm [2000, August 4].

[9] Gipe, P. (1995). *Wind Energy Comes of Age*. New York: John Wiley & Sons, p.121.

gearbox, which contains the low speed and high speed shafts. Through these two shafts, slowly rotating, high torque power from the hub is converted to high speed, low torque power. This mechanical energy is converted to electrical energy by the electrical generator. The electrical energy from wind turbines running at constant speed is connected directly to the grid.

The usage of wind power was limited except for small-scale usage such as pumping water purpose in rural area. However it acquired another potential of supplying power to the grid since the world's first electricity generating wind turbine was built in 1891 by Poul la Cour, Danish wind energy pioneer.

A typical modern wind turbine has a rotor diameter of 43 metres and a 600 kW generator. Depending on wind condition it produces between 1- 2 GWh. This is equivalent to the annual electricity consumption of 300 to 400 European households[10].

Emerging importance of wind energy

Before rural electrification was developed, wind power had been used for powering remote areas as stand-alone power system. Development of grid-connected system was evolved later. It was during the 1970's shortages of oil that the interest for generating electricity in wind power increased and intensive research was promoted. Its possibility is even more discussed recently because of environmental concern. Energy has caused environmental problems throughout its life cycle. Extraction of raw material for energy production disturbs surroundings. Energy production and transportation emit several air pollutants. Air pollution is caused during consumption phase as well. Finally, at post consumption phase, disposal of energy waste is serious environmental hazard.

There are two distinct atmospheric problems, which are closely related energy: the generation of acid rain and climatic change stemming from the greenhouse effect. They have certain similarities: are complicated and contain large uncertainties; long-lasting; have trans boundary nature; potentially irreversible; are unintentional by-products of widely supported economic activities; and require substantial investments of present resources to hedge against the prospect of large future environmental changes.

Compared to acid rain, whose effects develop regionally, greenhouse effect develops more globally. This effect is induced by carbon dioxide, chlorofluorocarbons, methane and more than a dozen other gases in concentration in the atmosphere. Carbon dioxide is the most significant agent because of its quantity. The amount of CO_2 in the atmosphere has risen steadily since the industrial revolution in 19th century largely as a result of the combustion of coal, oil, and natural gas on an expanding scale. "In 1850 the global CO_2 concentration in the atmosphere was roughly 280 parts per million, whereas by

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[10] Danish Wind Turbine Manufacturers Association. (2000). *21 Frequently Asked Questions About Wind Energy*. http://www.windpower.dk/faqs.htm [2000, August 6].

the late 1980s it had increased to approximately 350 parts per million"[11].

There is still uncertainty around greenhouse mechanism. The fact is that there are many weather extremes causing blackout of power supply system around the world recently. In 1998 January the ice storm hit eastern Canada and the northeastern US. Tornados caused devastation in France and southern England. Another swept into southeastern Russia from the Black Sea, cutting power and sinking two ships. Australia had heavy rain resulting in widespread flooding in Queenland. It is important to be aware of that modern society depending on large-scale CO_2 emitting power system with long transmission line is quite vulnerable to natural disasters. If these weather extremes are result of climate change energy sector is the cause at the same time suffering the effect.

Energy sector is one of the largest CO_2 emission sources. In order to search for the solution, in 1997 Conference of the parties under Climate Convention was held where they adapted binding goals for reductions of different greenhouse gases and sectors. As a first step industrial countries have committed themselves to stabilize their emissions in 2000 to the same level as in 1990. Wind power is considered to be one of the most important energy sources that can address this climate issue, as it is basically carbon free energy source. And it has a large potential to replace fossil fuel based electricity production[12].

The locality nature of wind power (being locally available within the country) is also paid attention to as it can contribute to solve a basic problem of modern society, i.e. the problem of secure supply. After the two oil price shocks in 70s and 80s, each country has been searching for alternative to fossil fuel to reduce dependency of energy imports. As wind is local and decentralised in nature its utilisation is considered to promote energy self-sufficiency of the region.

Recent trend of energy supply system is more and more away from centralised large-scale and toward decentralised small-scale. Authority, power utility and business society have been realised that smaller stations are easier to locate. They can be constructed and brought into operation more rapidly, enabling to make more prompt return on investment. They can be sited closer to consumers, or even on their cites thus reduce the necessity of long grid construction and its costs and losses that are accompanied[13]. New generation will be based on small-scale decentralised power rather than larger centralised precursor. Wind power is scattered in nature, i.e. decentralised and appropriate to play important role in new supply system.

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[11] Climate. (2000). In Encyclopædia Britannica Online. http://www.eb.com:180/bol/topic?eu=109117&sctn=3 [2000, August 7].

[12] Korsfeldt, T. (2000). The social impact of wind power. In: *Windformer*, Västerås, 8 June 2000.

[13] Patterson, W. (1999). *Transforming Electricity. The Coming Generation of Change*. London: Earthscan Publications, p.12.

Negative aspects of wind power

Although it has many benefits, wind power has some drawbacks. One of the largest limitations for wind power usage has been said its small scale. It cannot provide power at a much larger scale than necessary for water pumping and grinding. Secondly it is completely dependent on wind resource. In other words it has intermittent and diffuse nature. This variability has seen major drawback from technical point of view. It was considered less reliable than larger machines based on thermodynamic processes.

Noise during turbine operation is major environmental impact. Two major types of noise from turbines are: aerodynamic noise caused by the interaction of the turbine blades with surrounding air, and mechanical noise created by all of the moving parts in the nacelle. Their public perception are, however, not absolute, i.e. dependent on background noise level, existing amenity level, socio-economic factors and general attitudes to wind energy. Another impact is visual intrusion of the turbines. Again its perception is dependent on aesthetic values, existing level of visual amenity and attitudes to wind powers[14].

Cost is a central problem. Wind power is regarded as expensive source compared to conventional fuels. Fossil fuels and nuclear power that are heavy subsidised from the state hold better advantage to alternative energy including wind power. In addition the price for conventional fuel does not reflect its hidden effect (externalities) that they bring about. Externality is an economic term that refers to environmental problems and explained as the phenomenon that one individual or firm affects the wellbeing of others[15]. Above-mentioned greenhouse effect is one of the major externalities that conventional fuels create. Market price does not include social cost for reducing greenhouse effect nor avoiding it. Market does not appreciate the environmental benign quality of wind power.

Directions to overcome these weaknesses

Small-scale, decentralised and intermittent character of wind power will not be a limitation in the future when more power is demanded in small scale. In fact it is discovered that in Europe and a number of other places wind speeds happen to be positively correlated with peak electricity consumption, i.e. more wind in the daytime than at night and more wind in winter than in summer. The role of wind power in smoothing demand and supply balance will be important.

Many efforts have been done to reduce noise from wind turbine. The performance is increasing

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14 European Commission. (1995). *ExternE: Externalities of Energy - Vol.6 - Wind and Hydro*. Brussels: Official for Official Publications of the European Communities.

15 Turner, R. Kerry, Pearce, David & Bateman, Ian. (1994). *Environmental economics: an elementary introduction*. New York: Harvester Wheatsheaf, p.79.

dramatically. Modern wind turbine (500 kW) emits less noise compared to 10 years vintage machine (55kW)[16]. In addition at offshore sites, which is becoming main development recently, this aspect is less important than at onshore locations.

The current climate convention agreement is to stabilise emission of greenhouse gases in 2000 in comparison with 1990. For example when 10% of electricity comes from wind power by 2020 annual savings of CO_2 will be 69 million tonnes in 2005, 267 million tonnes in 2010, and 1,780 million tonnes in 2020[17]. This implies that expansion of wind power may be desirable even if costs are comparatively high.

[16] Gipe, P. (1995). *Wind Energy Comes of Age*, p.385.

[17] European Wind Energy Association, Forum for Energy and Development and Greenpeace. (1999). *Wind Force 10*. http://www.greenpeace.org/~climate/ [2000. August 8].

3. General Description of Drivers and Barriers to Wind Power Development

General environment and some specific conditions might enable wind energy to penetrate in the market. This chapter will try to overview some promoting and impeding factors. The former is classified as drivers and the latter as barriers. The chapter is intended to give guideline for following chapters. There are several categories of drivers and barriers: those from national policy point of view, those from wind turbine manufacturer point of view, those from investor perspective and those in general perspective.

It should be noted that it is not always clear which of these drivers and barriers are predominant. Although national government commitment seems indispensable wind power could develop without it and even with strong government initiative, other factors can hinder its development.

3.1 Drivers

Most of drivers are arrangements deliberately established for wind energy development. It means that its environmental benign nature alone cannot be driver with the exception of consumer behaviour.

Absence of political uncertainty

Strong political will to support wind energy is indispensable for its development. The reason is obvious. As energy security is national interest, governments have been actively engaged in achieving it for long time. As a result, the energy sector is one of the most state-controlled sector in a country. Since it involves strong interest parties, it takes time for “newer” technology such as wind energy to diffuse in the market. It can be claimed that it is policy makers’ responsibility to supervise institutional changes towards favourable direction for wind energy[18].

Consistent national policy may result in strong domestic market for wind energy. When the national policy promises certain capacity of wind power installation for long future there is relatively reliable demand for manufacturers to meet. This guarantees them domestic market enough to finance continued development of new and more inexpensive turbines. Also from investors’ and bankers’ perspective when the country is politically stable and the role of wind energy is widely acknowledged, they can trust that the government will continue its policies. Owners of turbines can benefit as well. With the protection of a contract owner can avoid risk of losing money.

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[18] Jacobsson, S. & Johnson, A. (2000). The diffusion of renewable energy technology: an analytical framework and key issues for research. *J of Energy Policy*, 28, 635-37.

Favourable climate for wind power investments

Under present competitive energy market the promotion of renewables including wind energy needs supportive market regulation including investment promotion[19]. Wind power's ability to attract capital is determined by several conditions. Investment tax credit applied to capital investment can promote investments including wind power installation. The contract type is important. Fixed-price contracts are preferred to floating-price ones by investors and operators in that they ensure stable revenue from the investment and avoid risk due to fluctuating future energy prices. Contract length, particularly that of fixed-price contracts, is another factor[20]. In order to allow financiers to recover their investment safely, longer contract is more favourable than shorter one, as it is much easier to convince investors to finance wind project with longer contract.

Government initiative in liberalisation of electricity market

Even in deregulated electricity market the role of national government is crucial. Current transition from regulated to liberalised market may promote wind power development. It enables entry of small-scale non-utility generator including wind energy generator in a market that has been dominated by large-scale utility companies for long time. In order for wind energy to develop market for electricity produced by those generators have to be guaranteed. Here strong government initiative is essential. It is to establish non-discriminate market conditions for wind energy within established electricity market. It is necessary that the national government require utilities to purchase electricity from small producers at a fair and fixed price and to sell backup power to independent producers at non-discriminatory rates through legislation[21].

In the process of deregulation prioritisation of environmentally benign energy production technology including renewable energy will enable countries to improve the environment. In particular, favourable conditions for investments in renewable energy should be preserved.

CO_2 tax (Climate change issues)

The increasing greenhouse effect is a major global problem. Energy sector is one of the largest emission sources. The 1997 Conference of the parties under Climate Convention adapted binding goals for reductions of different greenhouse gases. As a first step industrial countries have committed to stabilize their emissions in 2000 to the same level as in 1990. Wind power is one the most important energy sources that can address this climate issue, as it is basically carbon free energy source. And it

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19 Commission Proposal COM(95)682.

20 Gipe, P. (1995). *Wind Energy Comes of Age*. New York: John Wiley & Sons, pp.29-31.

21 Jacobsson, S. & Johnson, A. (2000). The diffusion of renewable energy technology: an analytical framework and key issues for research. p.635.

has a large potential to replace fossil fuel based electricity production[22]. In addition introduction of carbon dioxide tax that intends to internalise some of environmental costs associated with energy production, such as costs of carbon dioxide emission, will increase competitiveness of wind energy compared with fossil fuels[23].

Financial incentives for wind turbine development and installation

There are three kinds of financial incentive to promote wind power development. A subsidy to wind power research and development encourages wind turbine manufactures or power industry to invest in research and development activities. Subsidies provided within ALTENER Programme in European Union are representative of this type. Second and third type supports general electricity supplier, end user, the farmer or landowner to purchase wind turbines. The former supports investment to build wind turbines. It takes the form of partly compensation of total investment costs. On the other hand the latter support production, i.e. the subsidy is paid per kWh for electricity generation from wind turbines.

Consumer behaviour

Currently electricity from wind energy with environmental benign property is more expensive than that from energy from conventional fossil fuel[24] and other renewables because it does not fully reflect social cost. Environmental conscious consumers are, however, probably willing to pay higher price for the former to the latter. This green consumerism helps further development of wind energy.

3.2 Barriers

Barriers are, except for political uncertainty and technical factors, related to the environmental concern. In legislations and people's mind wind energy is not completely considered as environmentally benign.

Political uncertainty

It is often mentioned that in many countries variable energy policy prevents stable investments in energy sector which need long term perspective. Without the prospect of an unchanging policy, investors are reluctant to spend money on investments including wind turbine installation. It is often

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[22] Korsfeldt, T. (2000). The social impact of wind power.

[23] Munksgaard, J. & Larsen, A. (1998). Socio-economic assessment of wind power – lessons from Denmark. *J of Energy Policy*, 26, 2, 93.

[24] Price of electricity from wind turbine is 28-33 öre/kWh (STEM (Swedish National Energy Administration). (1998). *Swedish Electricity Market 1998*. Eskilstuna: Swedish National Energy Administration, p.16) while average price from fossil fuel based plant is 19-25 öre/kWh in Sweden (SOU 1995: 139, p137).

the case that investors are unsure about future government policy toward wind energy. Neither industry is willing to invest on wind power without confidence of a lasting policy. Financial incentive (subsidies for wind turbine installation) alone may not be sufficient. Even more important is credibility of government that ensures present policy instruments to last. In this context disagreement among different political parties in the parliament concerning energy policy could be a decisive factor that hinders wind energy development.

Land use planning (environmental regulations)

Wind energy projects might meet objections from other part of society. When the site is already included in certain land use planning by national, regional or local government from other than energy policy perspective (such as nature conservation) it is difficult for wind developer to get building permit in that area. Even if it is not part of certain land use planning, in general, the more extensive and complicated environmental regulations the country has the more difficult to acquire the permission and build wind turbine. Usually land use planning and environmental regulation are closely related to public attitude toward environment. Sometimes it is connected to landscape or nature conservation movement by local people[25].

Environmental standard in the deregulated electricity market

Without strong government initiative to support wind power it is difficult for wind energy to develop in the deregulated market. Whether wind energy can enjoy benefit of liberated market depends on level of environmental standards in the new power market. In the deregulated market competition between different energy sources is unavoidable. So far expensive but environmentally benign wind energy manages to compete conventional energy through particular considerations such as subsidies from authorities. In the liberated market, however, it is difficult to keep such policy instruments and they are to be abolished in the long run[26] if the environmental standards are low in the market. Then it will be difficult for electricity from wind energy to compete with that from cheap conventional fossil based plant.

Public acceptance

Some local people oppose wind power projects from concern about their visual intrusion, noise and electromagnetic interference[27] from lack of knowledge. Although generally public acceptance of wind energy is high, specific local projects can meet local objection. Lack of communication between local

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[25] Stahl, C-I. (2000, June 20). Personal interview.

[26] Dalén, G. (2000, June 27). Personal interview.

[27] Street, P. & Miles I. (1996). Transition to alternative energy supply technologies. *J of Energy Policy*, 24, 5, 420- 421.

people and developers and local decision makers may give negative attitudes and even actions against local wind power development[28]. Public acceptance become limited when local people are estranged from the siting procedure and planning process is unclear and information dissemination on the project is poorly organised.

Technical issue

In order to contribute energy supply system power from wind turbines has to be connected to the grid. However sometimes it is difficult to connect wind sites to the existing energy infrastructure because of their distance and insufficient existing capacity of grid. Place appropriate for wind turbine installation with high wind resource such as seashore and off shore area has often weak network system[29]. It is difficult for turbine owners to build and connect to existent network because of difference in voltage in local and necessary infrastructure for wind power. This high cost of necessary investment for grid infrastructure is large barriers for wind developers to install wind turbines[30]. In addition to lack of rule about connection fee and responsibility of capacity enlargement, fluctuation in electricity supply from wind power have been considered as a drawback[31].

Table 1 below summarises the importance of each issues based on literatures and primary data (see Table A-1 in Appendix).

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28 Damborg, S. & Krohn, S. (1998). *Public Attitudes Towards Wind Power*. http://www.windpower.dk/articles/surveys.htm [2000, June 6].

29 STEM. (1999). *Energimyndighetens arbete med omställningen av energisystemet* [Energy Administration's work in energy system restructuring]. 1 januari 1998 – 30 juni 1999. Eskilstuna: Swedish National Energy Administration, p.39.

30 SOU 1999: 75. *Rätt plats för Vindkraften Del 1* [Right place for wind power] Slutbetänkande Vindkraftsutredningen, p.119.

31 Street, P. & Miles I. (1996). Transition to alternative energy supply technologies, p.420.

Table 1 Summary of drivers and barriers

		Factors	Importance
Drivers	Supply-side	- Strong government commitment	Very high
		- Market regulation toward investment	High
		- Climate change issue	High
		- Subsidies	High
	Demand-side	- Consumer demand for green electricity	Moderate
Barriers	Supply-side	- Lack of reliable energy policy	High
		- Environmental regulations	High
		- Deregulation of electricity market	High
		- Technical issues	Low
	Demand-side	- Public acceptance	Low

4. Danish Case (1980-)

In this chapter the Danish energy policy situation will be investigated. Important factors include among others, national government commitment, existence of agricultural machinery manufacturer as a crucial background for national wind turbine industry development and private individual ownership of wind turbines.

4.1 General Overview of Energy Policy

After oil crisis during 1979-80 an energy strategy called “Energy 81” was published in 1981. It was focused on not only energy self-sufficiency but also socio-economic and environmental considerations. The strategy set goal for 1000 megawatts capacity of wind energy by 2000. Around this time the number of wind turbines started to increase. In the beginning most of them were owned by individual. Gradually installation by wind co-operatives where a group of people share a wind power plant grows. As of 1998 83% of Danish wind power capacity is owned by individuals or wind co-operatives. Rest is owned by power companies.

In 1985 Denmark gave up nuclear development, which had been discussed for a long time. Presently Risø National Laboratory, which was originally found for nuclear research, carries out important studies in the wind energy field including research on aerodynamics, meteorology and wind assessment, structural dynamics and advanced materials. Its role in ensuring turbine safety is so significant that it became a world information centre for wind turbine technology.

In 1990 action plan “Energy 2000”, whose main objective was sustainable development in energy sector, was established. It was followed by “Energy 2000 – follow-up” in 1993. In 1996 “green tax package” was introduced and energy taxes were gradually increased in trade and industry sector. Three kinds of tax, i.e. carbon dioxide tax, energy tax and sulphur tax were increased, above all on coal and electricity consumption. Energy intensive industry is, however, not liable from ordinary tax rate[32]. Target for energy sector is substitution of coal to another energy fuel by 2028. In 1997 the Government decided to prohibit installation of new coal-based plant within the energy sector. Today investment support for converting district heating based on coal to bio fuel is provided. At the same time of coal-based boilers will be converted to natural gas and bio fuel based ones. In addition, voluntary agreements between the Government and industry have increased the capacity of renewable

[32] The most energy intensive process is exempted from energy tax and pays lowest carbon dioxide tax per ton.

sources[33]. In 1992 Law for Wind Turbines was enacted.

The Government published *Energy 21*, current action plan, in 1996. Its objective is among others sustainable development of Danish society particularly through active energy policy. The initiative set for this objective is reduction of resources utilization and environmental impact by the energy sector while positive influence on energy security, economy and employment is pursued.

In March 1999 the Government reached an agreement concerning electricity reform with the Liberal Party, the Conservative Party, the Conservative People's Party, the Socialist People's Party and the Christian People's Party[34]. With this agreement along with EU directive on the internal market for electricity, Danish electricity market is on its way to become a competitive market.

Liberalisation of the electricity market is gradually started from spring of 1999. Depending on their consumption, consumers are to have right to choose their suppliers from the 1999[35]. In near future electricity production and trade will be carried out under fully competitive condition in Denmark. The electricity sector will be released from current non-profit principle and turn to ordinary commercial activities. On the other hand, transmission and distribution grid will play important role as public infrastructure.

Current development in Denmark is directed toward offshore wind power development mainly from two reasons. The first reason is limited available land space. Denmark is densely populated country and accessible wind resources were already exploited. The second reason is quality of wind is much higher offshore than onshore. It means higher wind speed, low surface roughness and lower turbulence. Government has selected 5 sites for its development.

In 1998 Denmark has total energy consumption of 854,760 TJ (c.a. 237.4 TWh) of which final electricity consumption is 115,128 TJ (c.a. 32.0 TWh)[36]. Supply from wind energy is 10,005 TJ (2.8 TWh), which means 1.2% to total energy consumption and 8.6% to final electricity consumption. Figure 1 shows **electricity generation** from different source in Denmark during 1980- 1998. The

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[33] STEM. (2000). *Strategier för att minska koldioxidutsläppen* [Strategies to reduce carbondioxide emission]. Eskilstuna: Swedish National Energy Administration, pp.79-80.

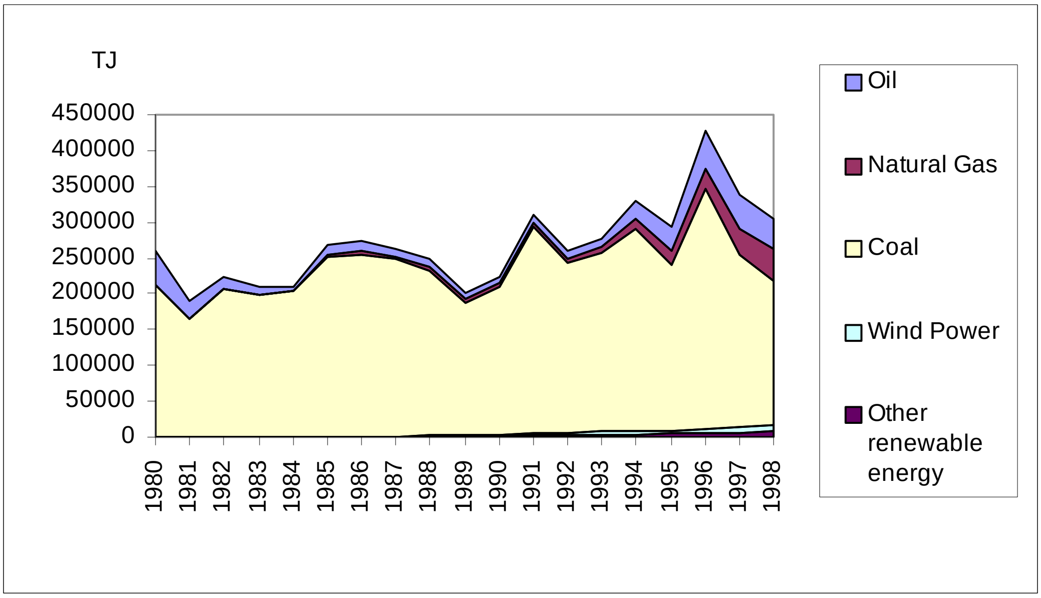
[34] Danish Act on CO_2 Quotas for Electricity Production (Act no. 376 of 2 June 1999). http://www.ens.dk/uk/energy%5Freform/bill%5Fno%5F234.htm [2000, June 14].

[35] Consumers with annual consumption of 100 GWh and over: from 2 June 1999. Those with 10 GWh and over: from 1 April 2000. Those with 1GWh and over: from 1 January 2001. All others: from 1 January 2003 (Danish Electricity Supply Act (Act no. 375 of 2 June 1999). http://www.ens.dk/uk/energy%5Freform/bill%5Fno%5F235.htm [2000, June 14]).

[36] Danish Energy Agency. (1998a). *Energy statistics 1998*. http://www.ens.dk/statistik/98/Filer/Energistat_98x.xls [2000, June 21].

difference between the consumption and production is the transformation loss, which amounts 164,462 TJ. Main source has been coal since 1980s.

Figure 1 Electricity production by source in Denmark (1980-1998)



Note: Other renewable energy includes hydropower, straw, wood, biogas and waste.

Source: Value taken from Danish Energy Agency. (1998a). *Energy statistics 1998*.

4.2 National Government Commitment

One of the commitments in Danish energy policy is related to CO_2 emissions, which is one of the highest levels par capita in the world. It is to reduce the total Danish CO_2 emissions by 20% from 1988 levels by 2005. This objective was first established in Energy 2000 and since then it has been a guiding principle in Danish energy policy. In addition as the outcome from Kyoto Climate Conference in 1997 EU agreed to reduce CO_2 emission by 8% from 1990 levels during 2008-12. For Denmark it is agreed to reduce 21% during that period[37].

One of the different points that distinguish *Energy 21* from previous action plans are that the emphasis on necessity of more consistent reform in electricity sector incorporating environmental aims with rapidly progressing liberalisation of electricity market. In its electricity reform the Government set several important frameworks including those for CO_2 emissions from electricity sector and for

[37] Danish Energy Agency. (n.d.) *Facts and Vision. Danish Policies and Measures to Combat Climate Change*. Copenhagen: Danish Energy Agency.

development of renewable energy for 2000-2003, consumer protection, environmental considerations and security of supply in the liberalised electricity market.

As energy sector accounts for more than 45% of total greenhouse gas emission in Denmark, a particular framework for CO_2 emission reduction from energy sector has been established. It is to set maximum limit of CO_2 emission every year and to reduce the limit gradually. The upper limit for total emission is set 23 million tons in 2000, 22 million tons in 2001, 21 million tons in 2002 and 20 million tons in 2003. Each ceiling is allocated as CO_2 quotas among electricity production companies. This quota system is designed to enable Denmark to continue to utilize the advantages of electricity exchange with the other Nordic countries. It means "CO_2 bank" system where quotas under the limit that have not been used can be allocated for use in subsequent years[38]. This quota system has significant impact on power company's future investment plan. It gives them confirmation of future national environmental commitment and a company can incorporate its future investment plan into certain national environmental commitment. If annual quota is not satisfied the production companies have to pay penalty of 40 DKK/ton CO_2.

In order to fulfil these targets wind power together with other renewable sources need to be expanded. Government estimates that domestic renewable sources should increase to an amount of 12-14% of total gross energy consumption by 2005. In supply terms it will be about 35% of supply. In Energy 21 target for wind turbine is to achieve capacity of 1500 MW by 2005. In the longer term capacity of 5500 MW will be achieved by 2030 out of which 4000 MW is expected to be offshore[39].

To meet this target the Government has required municipal and regional authorities to make plans for wind turbine siting through a planning directive. Although no quotas were set most counties have managed to select sites with good wind resources through extensive hearing procedure for local residents. More than 2600 MW capacity have been identified[40].

4.3 Policy Instruments and Legislations around Wind Power

Danish Government has been actively promoted wind turbine installation since 1970s. Not only supply-side help has been carried out but also demand-side policy, which is compatible with liberated market, is to be carried out in near future. It is one of Danish characteristics in wind power policy that private wind turbine installations have been continuously supported.

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38 Danish Energy Agency. (1999a). *Review of Energy Policy 1999*. http://www.ens.dk/pub/epr/epr99uk.htm [2000, June 14].

39 Danish Energy Agency. (1999b). *Wind Power in Denmark Technology, Policy and results*. Copenhagen: Danish Energy Agency. p.7.

40 Krohn, S. (1999). *The Wind Turbine Market in Denmark*. http://www.windpower.dk/articles/wtmindk.htm [2000, June 6].

Besides policy instruments background conditions are set up to facilitate wind power installation through Act on Spatial Planning.

4.3.1 Supply-side Policy (Financial incentives)

There had been four policy instruments that support wind energy development from supply-side in Denmark. First one is the installation subsidy of 30% of total project cost, which was introduced through renewable energy programme in 1979. This subsidy was gradually reduced and abolished in 1989 as industry matured and the price of wind turbine started to decline.

Second is production subsidy of DKK 0.27/kWh that was granted for private-turbine owners until the end of 1999. This consists from direct subsidy of DKK 0.17/kWh and carbon dioxide tax reimbursement of DKK 0.10/kWh. Power utilities, which produce electricity from wind power also get refund as CO_2 tax deduction on wind generated electricity. During transition period to liberated market system first part of production subsidy (direct subsidy) is paid under following rules. For small turbines with a capacity up to 200 kW, subsidy is given for 25,000 full-load hours, for middle turbines between 201 and 600 kW get 15,000 full-load hours and large turbines over 601 kW receive 12,000 full-load hours. CO_2 tax reimbursement is not changed.

Thirdly the Government requires power companies to connect private wind turbine to the grid and to receive and pay for electricity generated from wind power. Since 1993 the payment had been set to 85% of the utilities' tariffs (production and distribution costs) by law on Wind Turbines. The average buy-back rate was DKK 0.328/kWh in 1998. As most Danish electricity production is based on coal the buy-back rates for wind energy are tightly linked to the world market coal prices. It is uncertain whether this linkage is good or not but it means wind generated electricity has guaranteed market in Denmark. This rule is currently changing due to deregulation of the electricity market. In the transition period a settlement price of DKK 0.33/kWh is set as corresponding to the 85% rule.

The last instrument is a three-year replacement programme (1994-1996) for obsolete and/or misplaced wind turbines. First objective is to increase wind resource potential by increasing turbine size from old small turbines (usually 55kW turbines) to modern large units (usually 600-750 kW). Second is to improve turbine location. Early generations were often sited in areas where wind power utilisation is restricted today because they were located without official planning and zoning restrictions. Total fund of DKK 5.6 million was spent to subsidise the replacement of obsolete wind turbines with modern units up to 15% of cost or DKK 200,000 whichever is the lowest[41]. This subsidy scheme turned out to be not successful. Only 36 turbines had been substitute by new larger units during the programme

[41] OECD. (1998). Denmark. In *Renewable energy policy in IEA countries. Vol.2 Country reports*. Paris: OECD.

period. Other measures are currently being planned.

As of 1998 10 % of electricity is generated by renewable energy in Denmark. The Government intends to increase the share to 20% by the end of 2003 through the electricity reform. In order to ensure cost-effective development market mechanisms are to be introduced for trade in renewable energy. It means subsidy schemes, which are mentioned above, would be discontinued. Instead policy instruments to promote wind energy from demand-side are to be established. As the first step renewable energy purchase obligation scheme will be introduced from 2003.

4.3.2 Demand-side Policy (green certificate)

The Government set renewable energy quotas to the effect that all consumers are obliged to purchase certain share of electricity from prioritised renewable plants. At present purchase obligation is set at 20% by the end of 2003. With this compulsory purchase scheme the Government can ensure that 20% of the electricity consumption comes from renewable energy. In order to facilitate this system a green certificate system will be introduced. This system creates the green certificate market to compensate the limitation of ordinary electricity market that cannot attribute environmental benign quality of green electricity.

Green certificate is issued to the producer of electricity from renewable energy sources (RE electricity) by the authority. It includes electricity produced by wind energy, biogas, biomass, solar energy and wave energy and electricity from small hydropower plants under 10 MW[42]. Every year every consumer of electricity will be required to acquire certain number of these certificates according to his electricity consumption. At the moment the number is fixed at the 20% target.

It is the system responsible companies[43] who are responsible for undertaking the purchase obligation on behalf of their customers. Penalties are set when they are not able to fulfil their obligations. DKK 0.27/kWh has to be paid to the Treasury. This will function as maximum price for the certificates. Minimum price for the certificates is guaranteed as DKK 0.10/kWh by Danish Energy Agency. The certificate functions as compensation for price gap between electricity market price and RE electricity thus support the latter. Consumers have incentive to buy green certificates from producers until they satisfy the obligation thus certificate become valuable. When competition between suppliers is severe

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42 Danish Electricity Supply Act (Act no. 375 of 2 June 1999).

43 A company with a licence that has the overall responsibility of maintaining security of supply and for efficient utilisation of a coherent electricity supply system (Danish Electricity Supply Act).

and supply of RE electricity is increasing it is expected that the price for RE electricity will decline[44]. Through this system, RE electricity producer are guaranteed to receive market price for electricity plus price for the certificate in the competitive market.

In this way tradable green certificates is expected to increase the penetration of RE electricity production into conventional electricity market by stimulating demand. At the same time for the Government it serves as accounting system to verify whether the policy target is met.

In order to move to the new system smoothly RE electricity will be gradually allocated the certificates. As for wind turbines first smaller wind turbines of 10 years of age and latest models will receive the certificate[45].

To summarise the price for wind power generated electricity Table shows the difference between before and after the introduction of green certificate system.

Table 2 Price for electricity generated from privately owned wind power in Denmark

	Until 1999 (Before introduction)	From 2000 (Transition period)
Payment from distribution utility (85% of tariff)	DKK 0.31-0.38/kWh	-
Green certificates	-	DKK 0.1-0.27/kWh
Settlement price	-	DKK 0.33/kWh
Additional price subsidy	-	DKK 0.17/kWh
Direct subsidy	DKK 0.17/kWh	-
Reimbursement of CO2 tax	DKK 0.1/kWh	DKK 0.1/kWh
Total	c.a. DKK 0.6 /kWh	DKK 0.7-0.87/kWh

Note: As the green certificate has not fully introduced as of 2000 August the price for it is not yet settled. Settlement price is applied to new turbines elected before the end of 2002 for 10-year period.

4.3.3 R&D Programmes

The Government has supported several R&D programmes on wind energy. Two kinds of programmes are included in Government-sponsored R&D on wind energy: the Energy Research Programme (EFP) and the Renewable Energy Development Programme (UVE). The former has financed wind energy

44 Voogt, M., Boots, M.G., Schaeffer, G.J.& Martens, J.W. (2000). Renewable Electricity in a Liberised Market – The Concept of Green Certificate, *Energy & Environment*, 11, 1, 68.

45 Nielsen, S. Rønsholdt. (2000, August 21). Personal interview.

related research project since 1980. Project in 1998 round include: rotor investigation, research aeroelastics, determination of dampening of edge-wise vibration. The budget resulted DKK 15.11 million. The latter was established in 1982 to promote the technical potential for wind power use through R&D and demonstration of improved technology, to support optimisation of available wind resource, to contribute in removing barriers to wind energy use, to enhance Danish contribution in international co-operation and to promote Danish industrial development and export. It supported DKK 14.45 million in 1998[46].

The budget of EFP and UVE includes that for Test Station for Wind Turbines established at Risø National Laboratory, DKK 7.9 million. Its activities comprised information dissemination, ad hoc assistance to the Energy Agency, international cooperation with other test stations, secretariat for the Danish certification and type approval scheme, inspection of major failure of turbines and development of test methods.

4.3.4 Legislations

Energy 2000 objective alone does not ensure the expansion of wind power as the location option for new wind energy projects in good wind conditions are restricted from other interests. Therefore, to maximise wind energy resource value coordinated spatial planning with other interests is required[47]. With Act on Spatial Planning environmental protection activities are increasingly incorporated into spatial planning and so is framework for siting land-based wind turbines.

Spatial planning in Denmark has three levels: national planning, regional planning in the counties and local and municipal planning in the municipalities. Required by the national spatial planning the counties designate areas in the regional plans where new energy projects can be sited. In response to the regional plan municipalities prepare local wind turbine plans, which prescribe the place turbines are to be installed and the method (individual installation, clusters or farms) and detailed conditions (type of tower, colour, etc). Counties issue zoning permits and installation permits to the municipal plan according to the Act. Every county sets up guidelines for regional planning which lay down the general stipulation for wind turbine deployment in its county. Spatial planning also emphasises the importance of involvement of power industry in such a manner that its view can be taken into account in the planning and that it can prepare the expansion or strengthening of grid, which will be connected to wind turbines.

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46 Danish Energy Agency. (1999b). *Wind Power in Denmark Technology, Policy and results*. pp.16-17.

47 Ministry of Environment and Energy. (1995). *Municipal planning for wind energy in Denmark: examples and experience*. Copenhagen: Ministry of Environment and Energy, pp.60-62.

Since 1992 three previous acts, the Conservation of Nature Act, the Management of Nature Act and the Prevention of Sand Drift Act are merged into Environmental Protection Act. It deals with general protection of habitats. With this act siting of wind turbines are regulated. It prescribes proximity guidelines such as distance from turbine to coastline (300m), lakes and streams (150m), forests (300m), ancient monuments (100m) and churches (300m). Other than these protected sites no specific permission in terms of building codes was required in installation of land-based wind turbine. Environmental assessment based on environmental Protection Act was not required earlier. It surely has facilitated installation of land-based individual wind turbines[48].

The most important legislation related to wind turbines in Denmark is the approval scheme based on a type approval[49] and a certified quality system. It was shared desire by wind turbine manufacturers, owners and authorities to develop a consistent set of rules for approval of turbines. Consequently a set of rules has been established in "Technical Criteria for Type Approval and Certification of Wind Turbines in Denmark." Danish Energy Agency is responsible for administration of the scheme and Risø National Laboratory has been assigned the task of secretariat and information centre for the scheme since 1979. It issues licenses or type approvals including the test and measurements for the approvals. In order to assist the Agency advisory Committee consisted of representatives form the Danish Wind Turbine Manufacturers Association, the Danish Wind Turbine Owners Association, insurance companies and the electricity utilities has been formed. For technical issues a technical committee, which comprises the authorised bodies to provide services under the Danish scheme for certification and type approvals, has been set up.

4.4 Industry Perspective

4.4.1 Wind Turbine Industry

Danish wind industry was born by several fortuities. Existence of significant wind resource with background of traditional windmills being common sight on the landscape was a good starting point for wind industry to develop, so was also the existence of a manufacturing sector with good engineering skill.

When first oil crisis occurred in 1973, some people suggested possibility of wind power as alternative

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[48] Today when turbines tend to be installed in clusters or in wind farms environmental assessment is required for those constructions.

[49] Type approval is a verification of the wind turbine design according to an approval scheme (Danish Energy Agency. (1999b). *Wind Power in Denmark Technology, Policy and results*. p.15).

to imported oil. Most of them were technically interested in 200kW-Gedser Wind Turbine[50], which were installed by an engineer at the SEAS power utility. Based on the Gedser design, Christian Riisager, a carpenter from west Jutland, managed to scale output down to 10kW and build 30 machines all over the country. Some manufacturers of agricultural machinery (e.g. Vestas, Nordtank, Bonus, Nordex and later Neg-Micon) soon recognized the possibilities of growing wind turbine market[51]. Today they dominate not only domestic market but to some extent, also the world market with their advanced engineering knowledge.

Government policy also helped wind turbine industry development. It is national consensus in Danish politics that national policy toward investment including that of wind turbines should not be changed because of its long term nature. It means that irrespective of ministerial party investment policy has not been amended. This characteristic has helped promotion of wind turbine investment in Denmark[52], which in turn, kept constant demand for wind turbine.

Another factor is existence of foreign demand. In the 1980s strong wind was blowing in California. In addition to business energy tax credit of 10% (later became 15%) created by the Public Utility Policies Act (PURPA) and investment credit 10% to encourage capital investment, California State set several policy instruments to promote alternative energy source to fossil fuels. 25% state tax credit for investments and most favourable purchase power rates in the States boosted wind business in California. At that time Danish wind turbine industry was only one who was ready to meet this huge demand. Through Great California Wind Rush Danish machine succeeded in gaining half of the capacity installed. Track record of Danish turbines in California created so-called "Danish Concept"[53] which dominates world wind turbine market today. Since then foreign demand has been an important driving force for wind industry development in Denmark. At the same time broad groups of the Danish population were demanding modern wind turbines. With tradition of skill in metal fabrication it was not difficult for Danish manufacturer to produce wind turbines. It was opportune for wind energy development that in Denmark both supply and demand for wind turbine has been existent in domestic market and also huge demand in foreign market. Danish wind turbine market is by now already matured. Strategy of wind turbine industry is naturally toward abroad. Currently 50% of wind

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50 It is prototype of all Danish wind turbines developed in 1956. It will be explained in 4.4.2 power industry.

51 Krohn, S. (2000). *Danish Wind Turbines: An Industrial Success Story*. http://www.windpower.dk/articles/success.htm [2000, June 29].

52 Kjær, C. (2000 June 29). Telephone interview.

53 It stands horizontal axis with three blades, upwind design with fixed speed operation and direct grid connection (Krohn, Soren. (1999). *The Wind Turbine Market in Denmark*.).

business in the world is directly or indirectly related to Danish wind turbine industry[54] and its annual turnover reached DKK 11 billion in 1999[55].

4.4.2 Power Industry

Danish power industry was interested in utilising wind power already after World War II. This interest led to start of an R&D programme on wind energy at SEAS power utility. As a result of this programme 200kW-Gedser machine was build in 1957. Gedser turbine was much larger than contemporary 10kW turbine. From the beginning interest of the power industry had been on large-scale turbine. Later in the early 1980s power companies build two experimental 630 kW machines, which were also much larger than the commercial type at that time. Neither Gedser nor 630kW machines were commercially successful. The electricity costs were much higher than that of fossil fuel based power plants or smaller scale wind turbines.

Danish power industry has participated in industry scale research programme since 1970s when governmental R&D started[56]. It can be pointed out that Power industry has focused on R&D rather than in the short run commercial purposes. One reason is that it had been under public service obligation until recently. Power industry had public service obligation to ensure universal service to all customers in a region at the same tariff. It was based on non-profit principle, which means it was not allowed to earn profit from its activities. This implies that power industry was only allowed to invest in renewable energy including wind power for research and development purposes. It has erected wind power capacity of 100 MW in 1992 and another 100 MW in 1992 but its installation so far has been mainly in agreements with the Government[57].

Recent electricity reform, however, is drastically changing power industry's investment strategies. Previous highly central planning task whose ultimate purpose was to deliver electricity at lowest price to consumers is replaced by the profit motive. Power industry now makes decision to seek profit in order to survive in the liberalised market. From now on wind power is an important part of power industry's investment strategy from commercial point of view[58].

Its role in R&D activities, however, will still remain important in the future. Presently power industry focuses on off shore turbine development where the R&D is crucial. It has a plan for large-scale

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[54] Nielsen, S. Rønsholdt. (2000, August 21). Personal interview.

[55] IEA. (2000). *IEA Wind Energy Annual Report 1999*. Colorado: National Renewable Energy Laboratory, p47.

[56] Danish Energy Agency. (1999b). *Wind Power in Denmark Technology, Policy and results*. p.9.

[57] Morthorst, P.E. (1999). Capacity development and profitability of wind turbines. *Journal of Energy Policy*, 27, 13, 782.

[58] Kristoffersen, H-E. (2000, July 24). Personal communication.

investments to install 750 MW before 2008 following the agreement with the Government[59].

4.5 *Wind Co-operatives and Individual Turbine Owner's Perspective*

The Danish electricity supply system has traditionally been self-organising without legislative regulation since the 19th century. Electricity plants were municipally owned in urban areas, while in the rural areas they were owned by co-operative societies whose members were the individual consumers[60]. As wind power sites were in rural area they have been naturally managed by co-operatives. This tradition is still widespread and it is one of the main characteristics in wind power development in Denmark that private individual are significantly involved. As of 1997 private individuals, either as members of wind energy co-operatives or as whole owners of a wind turbine (farmers), account for about 80% of installed wind power capacity in Denmark. There are 1500 co-operatives[61] and 100,000 families own shares in local wind turbine[62]. Particularly it is a recent trend that the number of wind turbines owned by single persons is increasing[63].

As wind turbines are owned by local people through the wind co-operatives or guild, there are less local objection to their installation. At the same time the ownership was restricted in that member owners have to live within a distance of 3 kilometres from the turbine[64]. The guilds eventually organised as the Danish Association of wind turbine owners[65]. The association have affected the development of wind energy in the country profoundly. It contributes to Danish wind turbine industry's development by publishing the technical description of each turbine produced with a record of its performance and the survey of owner satisfaction. This led to improvements. Another important feature of the association is that since 1991 it offers insurance against damage and consequential losses and the risk of the manufacturer going bankrupt during the guarantee period[66]. It

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59 Danish Energy Agency. (1999b). *Wind Power in Denmark Technology, Policy and results.* pp.9-10.

60 Danish Electricity Supply Act (Act no. 375 of 2 June 1999).

61 Bkerre A. (2000, September 5). Telephone interview.

62 Krohn, S. (1999). *The Wind Turbine Market in Denmark*.

63 Morthorst points out the driving force of private individual investment as economical reason, i.e. profitability of investment (Morthorst, P.E. (1999). Capacity development and profitability of wind turbines. *Journal of Energy Policy*, 27, 13, 781-782).

64 This criterion of residence was amended several times. Presently a member owner has to live or work within borough where the turbine locates or own as house or real estate there.

65 Moore, C. & Ihle, J. (1999). Renewable Energy Policy Outside the United States. *Renewable Energy Policy Project Issue Brief*, No.14.

66 Tranæs, F. (1997). *Danish Wind Energy Co-operatives Part 2.* http://www.windpower.dk/articles/coop2.htm [2000, June 13].

has protected turbine owner's interest and thus contributed to the wind energy development in Denmark.

The association has been influential politically. Together with Danish Wind Turbine Manufacturers Association it formed strong alliance in the politically fragmented parliament by exercising thousands of wind turbine owners support to win their claims. One of the supports that it won was to include individually owned single turbine in 1991 agreement between the government and utilities on future wind energy development. It means the intention of government planners and utilities to direct turbines into easily manageable wind farms and clusters was not realised, and the Danish wind development characteristics of individual engagement was maintained.

In addition to co-operative ownership tradition there are also factors that help co-operatives and individual turbine owner to purchase wind turbine, an expensive capital investment. There is non-governmental financial support for purchasing turbines. Danish banks and finance societies are ready to support wind plant developers by providing favourable loan offer (10-12 year loans at rates for 60-80 % of installation cost)[67].

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[67] Gipe, P. (1995). *Wind Energy Comes of Age.* p.62.

5. Swedish Case (1980-)

This chapter will overview important factors that shape wind energy policy and its development in Sweden. It is identified that parliament politics, related national legislations, building permit application are main points in Swedish energy policy.

5.1 General Overview of Energy Policy

In addition to the oil crisis the accident at Three Mile Island in Pennsylvania in the United States in 1979 gave Sweden as one of nuclear energy dependant countries, massive impact. The referendum on nuclear power was held next year in Sweden, which resulted the parliament to decide to phase out all of the operating reactors by 2010. In 1981 the revised energy act was ratified. Unlike in Denmark, however, the priority was on mainly reduction of oil import dependency. Increased consumption of renewable energy source and promotion of energy conservation were also stated as one of its means. This oil saving/substitution policy resulted in increased consumption of electricity[68]. Electricity consumption increased from 94.5 TWh till 138.9 TWh out of which residential and service sector increased from 43.0 TWh till 63.0 TWh in 1980s[69].

The accident in Chernobyl in Ukraine seemed to prompt Swedish energy system to reduce its nuclear dependency. However, energy policy was politicised in the parliament politics and was treated as a political tool between parties. It was difficult to pursue phase-out policy because of complicated interest matters. In 1991 the Social Democrats, the Liberal party and the Center party concluded an agreement on energy policy. It certified that the objective of energy policy is to create the conditions for a long-term and short-term supply of energy on internationally competitive terms and to promote economic and social development based on environmental sustainability[70]. Based on this agreement the revised Energy Policy Bill was published in 1991. The Bill clarified the guideline for the timing of the start of the nuclear phase-out and the proceeding pace. According to the Bill they are to be determined by the results of electricity conservation efforts, the availability of electricity from environmentally acceptable power source and the necessity of keeping electricity prices competitive in international terms. It also laid down greenhouse gas emission target, 5-year development programme for energy saving, among others, electricity conserving technology and investment subsidies for new electricity generation technology development. Promotion of renewable energy sources was also mentioned. By this revised Bill in 1991, SEK 1302 billion was granted as investment subsidies to renewable energy

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68 For example switch from oil heater to electricity heater was promoted by financial incentive.

69 STEM. (1999). *Energy in Sweden. Facts and figures 1999.* Eskilstuna: Swedish National Energy Administration.

70 IEA. (2000). *IEA Wind Energy Annual Report 1999.* p.137.

source based new electricity production system including wind power, solar power and bio fuel based cogeneration. The guidelines established in the Bill are being subjected to re-evaluation.

As the result of investment subsidy electricity generation from wind turbine started to rise from 1991. It increased from 11 GWh in 1991 up to 300 GWh in 1998. Most of wind turbines are cited on the coastline in southern part of Sweden. Except for the ones on the county of Gotland, all of the wind turbines are situated on land[71].

CO_2 emission is specifically stipulated in the Climate Policy Bill in 1993. Its target is to stabilize at the 1990 level by the year 2000, after which to decrease. Based on 1991 Energy Policy Bill a parliamentary Energy Commission was appointed in the spring in 1994 to examine the ongoing programmes for transformation of the energy system and to analyse the need for changes and additional measures. The work of the Commission was presented in the end of 1995[72]. After negotiations another interparty energy policy agreement between Social Democrats, the Center Party and the Left Party was reached in 1997. The main points of the agreement, Toward a Sustainable Energy Supply, include[73]:

- The two reactors at Barsebäck are to be closed down, the first prior to 1998 July 1 and the second prior to 2001 July 1. The condition for the shutdown of the second reactor is that new electricity production and electricity conservation compensate for the deficiency of electricity as the result of shutdown.

- Special measures will be adopted to reduce electricity consumption and to increase electricity and heat production capacity based on renewable energy sources. Electricity saving should be achieved by reducing the use of so-called interruptible electric boilers, conversion and energy-saving measures in houses with direct electric heating, increased connection to district heating and creation of new electricity production from renewable energy sources through investment support and technology procurement.

It also contained a strategy for reducing the energy sector's impact on climate. The strategy is founded on the idea that an equitable distribution of commitments and mitigation costs are necessary for successful international co-operation such as climate issue. Agreement within EU after Kyoto Conference approved Sweden to increase greenhouse gas by 4% compared to 1990 levels during

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71 SOU 1998: 152. *Vindkraften en ren energikälla tar plats* [Wind power clean energy source launches]. Lägesrapport December 1998 från Vindkraftutredningen, pp.15-18.

72 SOU 1995: 139. *Omställning av energisystemet* [Restructuring of the energy system].

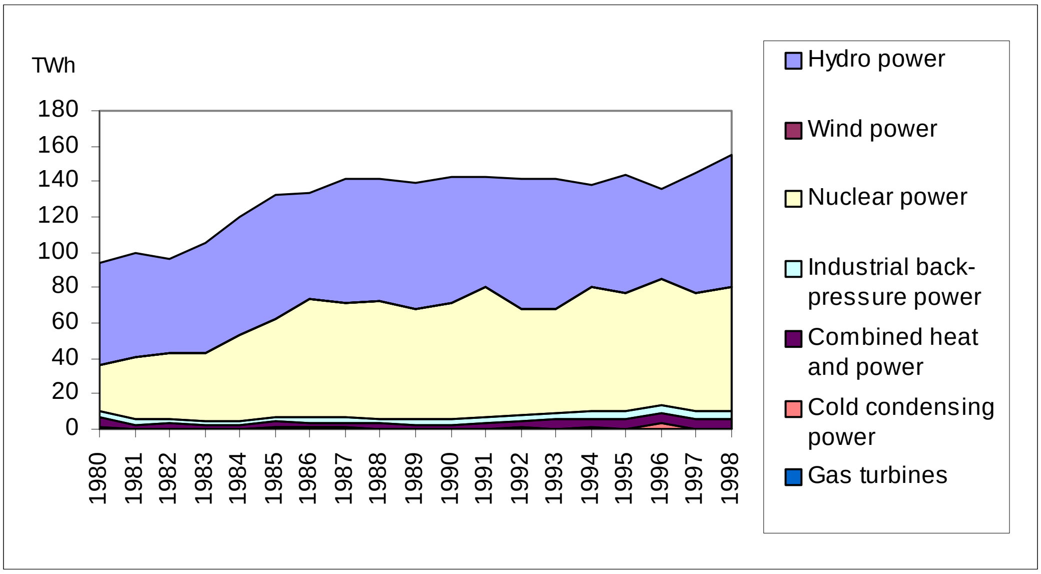
73 STEM. (1999c). *Energimyndighetens arbete med omställningen av energisystemet* [Energy Administration's work with restructuring of the energy system]. 1 januari 1998 – 30 juni 1999. Eskilstuna: Swedish National Energy Administration, pp.6, 14-15.

2008-12[74].

One important aspect in Swedish electricity market that should be noted is that it has been deregulated since 1996 through the new Electricity Act. The primary difference to previous regulated market is that electricity network operations are separated from exchanging and generation of electricity. Through grid separation every generator has equal opportunity to sell electricity to its customers[75].

As of 1998 Sweden has total energy consumption of 480 TWh of which final electricity use is 143.9 TWh. Supply from wind energy is 0.3 TWh, which consist of 0.2 % of total electricity production[76]. In Figure 2 the electricity supply structure is shown. Dominating electricity sources are hydropower and nuclear power since 1980s. Figure 2 illustrates Swedish electricity production by source since 1980.

Figure 2 Electricity production by source in Sweden (1980-1998)



Note: Industrial back-pressure power, combined heat and power and cold condensing power contains both fossil fuel and bio fuel including peat.

Source: Value taken from STEM. (1998). Swedish Electricity Market 1998.

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74 As national circumstances that Sweden had already undertaken mitigation measures were taken into account, burden sharing agreement translated overall 8% CO_2 emission reduction commitment into 4% increase (STEM. (1999c). *Energimyndighetens arbete med omställningen av energisystemet*, p12).

75 STEM. (1998). *Swedish Electricity Market 1998*, p.3.

76 STEM. (1999). *Energy in Sweden. Facts and figures 1999*. Eskilstuna: Swedish National Energy Administration.

5.2 Related Legislations

As optimal wind turbine sites are open landscape with good wind condition without any buildings they have often high value from nature, culture and outdoor activity point of view. This view is reflected to land use planning where much emphasis is put on other interest than wind resource exploitation. In addition building wind turbine in such places requires consultation with several related legislations in Sweden. General stipulations on soil and water zone maintenance are found in Natural Resources Act (NRL) (1987: 12). It is mentioned that soil, water and its physical surroundings should be utilized in good way from ecological, social and national economically long-term perspective. Corresponding provisions have been enacted in Environmental Code (1998: 808)[77]. Besides for areas with higher natural and cultural value such as national park, nature reserve, nature protection area and natural monument, among others, Nature Conservation Act (NVL) (1964: 822) is applied[78].

Legislations concerning wind turbine construction are following 9 legislations[79]. Based on NRL Chapter 4 Government decides whether the installation is permissible or not. It is related to only large-scale installations. It is because their scale or other characteristics large-scale installations have huge impact on environment and their impact can involve conflict with other land use interest. Planning and Building Act, PBL (1987: 10) sets down general condition for building permission. With new Act on Technical Quality Requirement for Building (1994: 847) PBL prescribe general requirement for buildings and technical qualification of other structures including wind turbines. Together with Environmental Protection Decree (1989: 364) Environment Protection Act, ML (1969: 387) concerns the place and how environmental hazardous activity can take place with general and specific interest. NVL principally prohibits new construction within the protection line for beaches, i.e. 100 m from the sea, lakes and streams. It also consults wind turbine construction from nature protection side, i.e. biotope and animal protection perspective. If wind power affects ancient monuments consultation with Act on Cultural Monument (KML) (1988: 950) is necessary. Consultation with Water Act will be required if the turbine is cited over water and Continental Shelf Act (1966: 314) and Act on Economic zone (1992: 1140) are required for related issues. Other concerning acts are Electricity Act (1902: 71) for network licence over water and Line right Act (1973: 1144) for transference and connection to cable over special zone. Wind developer has to apply for different authorities for each of these acts when necessary.

Table shows overview of legislations related to turbine installation. It is classified with capacity or

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77 Rubenson, S. (1999). *Miljöbalken. Den nya miljörätten*. Andra upplagan [Environmental Code. New environmental right. Second edition]. Stockholm: Norstedts Tryckeri.

78 SOU 1998: 152. *Vindkraften en ren energikälla tar plats* [Wind power clean energy source launches]. p.35.

79 SOU 1998: 152. *Vindkraften en ren energikälla tar plats*. [Wind power clean energy source launches]. pp.43-45.

diameter of wind turbine.

Table 3 Overview of requirements for building permission of land-based wind power plants together with requirement for MKB in Sweden

Effect / Turbine diameter	Investigation requirement according to:				
	NRL Chapter 4	PBL	ML	NVL	KML
<2m turbine-diameter	-	Building permit 1)	-	2a) MKB 5)	4)
>2m turbine-diameter-25kW	-	Building permit / Detailed plan MKB 6)	-	2a-b) MKB 5)	4)
125kW- 1MW	-	Building permit / Detailed plan MKB 6)	Notification to the Commune	2a-b) MKB 5)	4)
1MW- 10MW	-	Building permit / Detailed plan MKB 6)	County permission MKB 7)	2b, 3) MKB 5)	4)
10MW	Government permission MKB 7)	Building permit / Detailed plan MKB 6)	National Franchise Board for Env. Protection permission MKB 7)	2b, 3) MKB 5)	4)

Note:

1) If the turbine diameter is larger than 2 meters or the power station is located in distance from border which is smaller than its height over the land or it is fixed in the building.

2) a. If the shore or another protected area that is affected requires dispensation.

b. Consultation with §20 can be required

3) NVL-inquiry prepares direct examination according to ML or NRL Chapter 4 without specific application by NVL which is effective for shoreline protection and consultation by §20.

4) KML will be appropriate if ancient monument or such area is affected.

5) MKB can be called for in NVL if that is necessary, i.e. decided case by case.

6) MKB requires detailed plan for industrial purpose if they can affect environment considerably.

7) MKB is obligatory for each application.

Source: Boverket. (1995). Etablering av vindkraft på land [Establishment of land-based wind power]. Karlskrona: Boverket, p.13.

5.3 National Government Initiative and Commitment

Since wind power programme started at Board for technical development in 1975 Swedish wind power research has been carried out emphasising mainly technical point of view[80]. This technical interest led to large-scale wind turbine development before its market evolved[81]. Long-term target for wind power field activities is to reduce the cost wind power and increase competitiveness of wind power production.

Swedish Energy Administration has supported commercialisation of Swedish technology in the wind turbine market where competition from Danish and German industry is hard. Therefore in order to be competitive it is necessary for Swedish concept of large-scale wind turbine to reduce cost and increase efficiency in electricity generation. Strategies for Energy Administration are to develop Swedish concept to ensure Sweden to have better possibility of Swedish industry creation. It has been engaged both in technology development and in investment support to promote installation of new wind turbines. Target for investment subsidy is to increase electricity from wind energy to 0.5 TWh 1998-2002.

In addition to technical perspective, recent purpose of wind power research has also the aim to study practical problems such as localisation issue as well as local acceptance inquiry and acoustic effect. Energy Administration is fully financing for 3-year research programme on wind power for the purpose of knowledge development on wind turbine meteorology, aerodynamics, structure dynamics, electricity and control technique, acoustic and social technical aspects. Programme includes among others new installation in mountains and water based wind power. Development and demonstration of new and more efficient technology are supported outside the research contribution. Programme has SEK 46.8 million budget since 1998 July 1[82]. These activities have been mainly carried out within the Wind Energy Programme at Aeronautical Research Institute since 1994[83].

In 1998 the Ministry of Environment appointed a special commission to investigate conditions for the localisation of wind power plant. Reports from the Commission reflect recent research direction. Based on the projection of continuing expansion of wind power they investigate overall picture of its effects on the land and water zone management and emphasise the necessity of data accumulation and

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80 Carlman, I. (1990). Blåsningen. Svensk vindkraft 1973 till 1990 [Gone with the Wind. Wind Power in Sweden 1973 until 1990]. In *Geografiska Regionstudier 23*. Upplsala: Uppsala University, pp.18-20.

81 Dalén, G. (2000, June 27). Personal interview.

82 STEM. (1999). *Energimyndighetens arbete med omställningen av energisystemet* [Energy Administration's work with restructuring of energy system]. 1 januari 1998 – 30 juni 1999. Eskilstuna: Swedish National Energy Administration.

83 IEA. (2000). *IEA Wind Energy Annual Report 1999*. p.143.

methodology for land use planning in relation to applications for permits for building of wind turbines, closer cooperation between central and local government and interested parties and criteria for deciding location of wind turbine. It also identifies a crucial aspect network infrastructure.

Energy Administration deems structured construction of grid is an essential factor for large-scale wind energy production strategy. It interprets that cost for reinforcing grid in wind turbine cites can be financed through the local investment programme to increase ecological sustainability provided that the annual production is over 21 GWh or effect of 10 MW capacity. It implies the cost for the network to a receiving station from existent regional grid and the receiving station will be covered by state subsidy, but on the other hand wind turbine owner has to pay connection cost for such receiving station[84].

Energy Administration considers that their recent initiatives to promote the development of wind power are decent. National governmental initiatives are, however, not yet fully understood and accepted by regional and local authorities. (National government can set up basic conditions for facilitating the development such as spatial planning.)

5.4 Policy Instrument around Wind Energy

5.4.1 Incentives on the Demand-side

Eco-labelled green electricity approved by the Swedish Society for Nature Conservation has attracted environmentally conscious consumer since its introduction in 1996. Under this scheme electricity generated from wind power, solar cells, biofuels and hydropower plants constructed before the criteria were introduced in 1996 are granted the eco-label "Good Environmental Choice[85]." The main customers are corporation who wish to appeal to their customers by distinguishing themselves as environmentally friendly from their competitors. The limitation of this system is that it does not appeal to individual household. And it may be incompatible with the liberated electricity market. Therefore new system similar to Danish green certificate system is to be introduced from 2003 January[86]. In this system every distributor and consumer is oblige to purchase certain amount of electricity.

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[84] SOU 1999: 75. *Rätt plats för Vindkraften Del 1* [Right place for wind power.] p.118.

[85] Swedish Society for Nature Conservation. (n.d.) *Mer om Bra miljöval el*. [More on good environmental choice electricity]. http://www.snf.se/bmv/prod-elektricitet/el-fakta.htm [2000, August 19].

[86] Widegren, K. (2000, May 25). Näringsdepartmentet pressmeddelande. Ekonomiska förutsättningar för elproduction från förnybara energikällor [Economic requirement for electricity production from renewable energy sources].

5.4.2 Financial Incentive for Supply-side

A buy-back system has existed since 1988. 1988 Electricity Law orders that local electricity distributor has reception duty to purchase electricity generated by independent producers within its geographical domain and it has to pay possibly reasonable price. From 1999 January 1 distribution concession system with special consideration for small-scale electricity production within which wind power was included was introduced. Distributors have to purchase electricity from small-scale production, which situates within geographical domain of concession. The price depends on administration cost and reasonable profit of distribution concession holder. As of 1999 February the payment to small-scale production is on average SEK 0.25/kWh of supplied electricity[87].

From 1997 July 1 Government started to grant an investment support for new wind turbine construction over capacity of 220 kW. Subsidy will cover 15% of total investment cost that is necessary for wind turbine to establish and operate with the exception of cost for applying building permit, pre-planning, land acquisition and rent during building period. Both private and juridical person can apply for the support. As authority's intention is to promote construction of cost effective plant in good wind condition sites the ratio between investment cost and normal annual electricity production is required to be higher than 4.60 SEK/kWh for subsidy application[88]. This subsidy programme will continue until 2002 June 31 with the budget of SEK 300 million for the 5-year period.

There are two kinds of turbine owner support at the moment. One is operational subsidy named environmental bonus, which amounts SEK 0.162/kWh. The other is a temporary subsidy of SEK 0.09/kWh which is given for the electricity generation for the year 2000[89]. In addition small-scale electricity producer receives "local grid value" of SEK 0.01/kWh from distributor[90].

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87 SOU 1999: 95. *Småskalig elproduktion samt mätning och debitering av elförbrukning*. [Measurement and electricity consumption debiting for small-scale electricity production]. p. 21.

88 NUTEK. (1998). *Statens energimyndighets föreskrifter om statligt bidrag till vissa investeringar inom energiområdet; vindkraft* [National regulation on investment support in energy sector; wind power by Swedish National Energy Administration]. Närings- och teknikutvecklingsverkets författningssamling (NUTFS 1998: 4) [Statute-book]. Stockholm: NUTEK förlag.

89 Lundström, G. (2000, April 14). Personal communication.

90 SOU 1999: 95. *Småskalig elproduktion samt mätning och debitering av elförbrukning*. [Measurement and electricity consumption debiting for small-scale electricity production]. p.21-22.

Table 4 Price for wind generated electricity in Sweden

	Until 1999 November (SEK/kWh)	After 1999 November (SEK/kWh)
Payment from distributors	0.25	0.145
Temporary subsidy from grid operator	-	0.09
Production subsidy (1997-2002)	0.05	0.05
Environmental bonus	0.162	0.162
Local grid value	0.01	0.01
Total	0.472	0.457

5.5 Industry Perspective

In Sweden electricity is mainly supplied by hydropower and nuclear power. The former has been developed and utilised for more than 100 years and the latter for 50 years. Both of them are considered as established technology. This fact gives large influence on Swedish society including industry.

5.5.1 Wind Turbine Industry

The history of Swedish energy policy shows these conventional energies have been developed by "the establishment" i.e. politicians, bureaucrats and business society with various interest. Many interests are mutually entangled around conventional energies. "The establishment" prefer to keep the current established system and are reluctant to make changes[91] unless they are put under pressure from outside. Swedish established energy system implies rather unfavourable condition for wind power development.

First, compared to conventional established energy such as hydro and nuclear, wind energy is considered as "new" energy in Swedish society. It is not easy for "the establishment" to accept and corporate new technology into conventional system. Second as both hydro and nuclear power provide large-scale electricity production, it is taken for granted that wind power shell supply in large-scale as well. Thus from the beginning research and development were focused on large-scale wind turbines, which is not always economical. The scale of current wind turbines that are commercially economical is said to be 500-600kW capacity. In Sweden two MW-scale prototype turbines were already installed between 1979 and 1982. As there was no local manufacturer who can provide such a large turbine most of early-installed turbines are imported from Denmark or Germany. It took around 15 years to

[91] Engström, S. (2000, August 11). Personal communication.

develop national wind turbine industry since governmental wind power programme started in 1975.

Today there are two wind turbine manufacturers in Sweden. Nordic Windpower was founded in 1990 by AFI-Industriteknik, an engineering consultancy company, and Hagglunds, at that time a manufacturer of railcars and military vehicles. Before starting the company they had been involved in the Swedish research and development programme on wind energy[92].

The other company, SW Vindkraft is established by wind turbine engineers in 1999. They have been engaged in technology development for the turbine before foundation of the company[93].

They consider that wind turbine technology is quite young and that there is large opportunity for them to improve cost-effectiveness of turbines. They do not, however, consider domestic market promising, instead they look outward to other European or Asian countries where demand for wind turbine is growing.

Currently the Swedish established energy system, which put unfavourable conditions on wind power, is partly changing. One sign is that ABB, a multinational electrical equipment manufacturer, is started to be involved in decentralised energy system. It has started to develop Windformer, new generation of wind turbine in 2000 June[94]. If the intention of “the establishment” is to restructure energy system toward decentralised energy, it can further promote wind power as one of them.

5.5.2 Power Industry

Current main sources of electricity, hydro and nuclear power, are good enough to maintain the power industry that have supported Swedish energy supply system for long time. They have contributed to the electrification of Swedish society with modern comfort and may well do so in the future. At the moment the supply from both sources is sufficient for the country to meet the demand even when one reactor at Barsebäck is closed, and the price is competitive. In addition neither hydropower nor nuclear power emit green house gases during their operation and they are not affected by climate issue discussion. Therefore there is no pressure for Swedish current supply system to transform into another system.

Swedish power industry has started wind power research in late 1970s. It was power industry that installed two MW-scale prototype turbines between 1979 and 1982. Their initial interests were on basic technical research rather than practical usage perspective. They focused on large-scale machines, as

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[92] Engström, S. (2000, August 25). Personal communication.

[93] Göransson, B. (2000, August 24). Personal communication.

[94] Korsfeldt, T. (2000). The social impact of wind power.

they believed large turbines were cheaper in the long run and recognised difficulties to find many suitable sites for small-scale wind turbines. A third reason is that large-scale turbines are more appropriate for future offshore sites because of maintenance costs, installation costs and cable costs.

Thus they consider wind power as only one option for future strategy[95]. It is not urgent from power industry's point of view to invest in wind energy for securing power supply from it today. Phasing out of other nuclear plants in future is one possible factor that might press for the development of another energy source. Environmental benefits have not motivated power industry to develop wind energy in Sweden so far. For them investment in wind energy today just implies closure of other plants that produce electricity at cheaper price. One of the few drivers that push Swedish power industry to wind power investment comes from consumer demand[96]. It is still corporate consumers who need to show their customer that they are doing good thing for environment. It is not yet considered to be a main and cheap energy source in near future. A possible driver is the introduction of the green certificate system. They expect market creation for the certificates where wind power play important role.

5.6 Independent Wind Developer's Perspective

In spite of complicated legislations to restrict wind power installation, weak policy initiative and passive industry the number of wind power plant has still been gradually increasing in Sweden since the beginning of 1990s. The driving force for this development has been the "green" movement by the public. It has been and still is private persons (households, farmers etc) that have invested their private money in wind power and created the market for the wind power industry[97].

The Swedish Windpower Association was established in 1986 by those who were interested in wind power, i.e. "green" people of all kinds, teachers, environmentalists etc. It has represented wind turbine owners' interest and contributed to improvement for economical condition for wind power in Sweden[98]. It has been actively working for improvement of status of wind power through participation in several governmental investigations (SOU 1998: 152, SOU 1999: 75 and SOU 1999: 95). Another activities are consultation with Swedish EPA, Swedish national defence, National Energy Administration and County administrative board in Skåne with regard to wind power deployment.

Since early 1990s members started initiating many wind projects. Some of them bought wind turbine

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95 Dalén, G. (2000, June 27). Personal interview.

96 Sjunnesson, L. (2000, July 26). Personal communication.

97 Wizelius, T. (2000, July 30). Personal communication.

98 Wiselius, T. (1994). Vind [Wind]. Del 3. Täby: Larsons Förlag, p.105.

originally planned by communal energy companies and established wind cooperatives. In this way first wind cooperative in Sweden was set up in Göteborg in 1993[99]. Today almost all Windpower Association members are wind turbine owners (private individuals, shareholders, members of cooperative wind power associations, etc) and many of them act as developers[100]. They can be termed as independent developers in that they are neither related to governmental activities nor that of power utility. As of 2000 there are some 50 wind co-operatives with more than 10,000 households as members[101]. It is estimated that these co-operatives hold 60% of wind turbine owners in terms of number of installed wind turbines in 1998[102]. The main driver for these independent developers is from the beginning concern about the environment including climate change and acidification. Their belief is through developing wind power it is possible to create a sustainable energy system and society.

For those wind developers main barrier for development is that it takes long time to get building permission from local government[103].

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99 Wiselius, T. (1994). Vind [Wind]. pp.63-66.

100 Wizelius, T. (2000, August 4). Personal communication.

101 Wizelius, T. (2000, August 4). Personal communication.

102 SOU 1999: 95. *Småskalig elproduktion samt mätning och debitering av elförbrukning*. [Measurement and electricity consumption debiting for small-scale electricity production]. p.29.

103 Wizelius, T. (2000, July 30). Personal communication.

6. Comparison of Danish and Swedish cases

In order to compare Swedish and Danish situations it will be convenient to give a brief summary of each case.

6.1 Review of Danish case

Denmark has several favourable conditions for wind power development. Fraction of decentralised characteristic in the structure of the electricity sector was larger due to wind power. Before the Government initiated centralised energy policy decentralised electricity supply system had been established by private individuals (farmers), municipality or co-operatives. These are based on coal or wind energy. Lack of centralised policy has had some negative effects to lead uncoordinated wind power development from land use planning. It cannot be denied that some of the early installed machines are sited at not optimal places from a wind resource perspective or place where wind utilisation should be restricted from environmental perspective. Nevertheless without early active installation by co-operatives, private individuals and municipalities, wind power would never have developed to the current level.

Denmark lacks electricity appliance manufacturer, which can be basis for nuclear industry. Instead it had agricultural machinery manufacturing industry, which developed into wind turbine industry. It was fortunate for these manufacturers that there was huge demand for their products in California in the 1980s before their own domestic market flourished. From the experience of exporting to California wind turbine manufacturers learned many lessons including technical problems of their products. Danish turbines gained established reputation in wind turbine in the world market by achievement in the Californian Wind Rush. Thereafter they met domestic as well as other foreign demand with improved products.

As for power industry traditionally it had interest in large-scale turbine development. Their activities have so far not been successful in developing commercial turbine but its contribution to technological development has been important and might be so in the future.

In addition to these circumstances Denmark has essential drivers, which are identified in chapter 3. Strong and consistent Government support is without doubt one of the dominating factors for successful wind energy development in Denmark. The Government has made most of every mean to clear the target in energy policy, i.e. to reduce CO_2 emission by increasing the share of wind power in energy system. Several policy instruments including spatial planning legislation are organised to support increased utilisation of wind energy. Assurance by the Government has influenced Danish financial sector positively to create favourable climate for wind power investments. The Government also commits itself to be active in supporting wind energy in the deregulated electricity market. By the end of 1999 the total installed capacity of wind turbines was around 1750 MW[104], which means that the target in Energy 21 to achieve 1500 MW of wind power by 2005 is already met in 1999.

Steady political support originates partly from environmental consideration and partly from its significance in national trade perspective. As of 1998 wind turbine consist 25% of export in Denmark[105]. In short wind turbine industry grew up to be one of major parties in Denmark. Together with Association of Wind Turbine Owner, it exerts political power. It is political agreement that it is national benefit to develop wind turbine industry in Denmark and this lead to structuring of favourable climate for wind power installation in practice. Several subsidy schemes and demand side policy consistently supported its investment. Coherent national government policy affects attitudes by the financial sector toward wind power investment. Thus there has been no political uncertainty concerning wind power development in Denmark.

Traditional co-operative or private ownership, which has been supported by the Government, has increased local acceptance of wind turbine. Thanks to consumer involvement, in Denmark there was not so much local objection to wind turbine projects, which had hindered wind power development in other countries. It has overcome environmental barriers as well. In Denmark local concern for the environment did not appear because local people were well informed and involved in wind power project.

The climate issue that limits emission of green house gases is critical for coal based energy supply system in Denmark but it can be a strong driver for wind energy. Denmark can further take advantage of existence of strong wind turbine industry to increase the share of wind energy. CO_2 tax has been partly contributed to support wind power in Denmark in that wind power generate electricity is reimbursed DKK 0.1/kWh which corresponds to it.

Through investigations into Danish system any barrier was not recognized which was identified in previous chapter. One of the few limitations in Danish wind power expansion is lack of space. It is plausible that the country is small size and available resources have been exploited. New sites is, therefore, expected to be off shore.

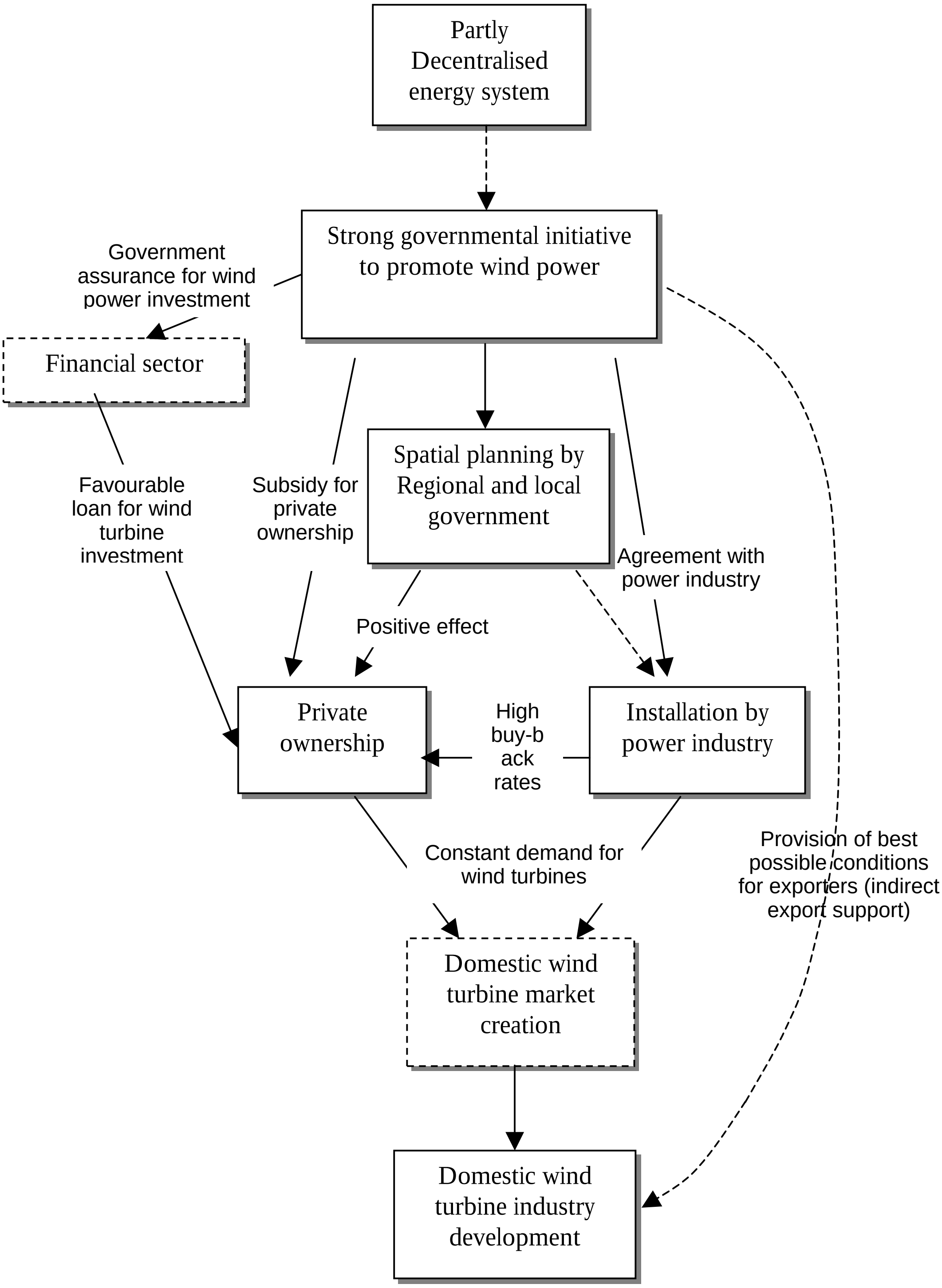
Wind power development in Denmark has mutually benefited from all of these factors. As shown on Figure 3 especially consistent political support is basis for wind power development in Denmark. And if any of industrial background, partly decentralised energy feature, co-operative or individual ownership and private involvement lacked from Danish society it would never have developed into

[104] IEA. (2000). *IEA Wind Energy Annual Report 1999.* p.49.

[105] Danish Energy Agency. (2000a). *Danish Energy-Sector Exports. Products and Consulting Services.* Copenhagen: Danish Energy Agency, p.52.

present form of wind energy system.

Figure 3 Schematic model for wind power development in Denmark



6.2 *Review of Swedish case*

Although Sweden is the first country to establish governmental wind energy programme its interest was not so high among public. However, as recent governmental investigation reports (SOU 1998: 152 and SOU 1999: 75) pointed out, Sweden has growing interest for developing wind power. Wind power is considered to be a type of energy appropriate to promote restructuring of energy system. It has, however, for several reasons, not yet been much developed.

A first reason why wind power is not yet widespread is lack of strong government commitment to it as a part of a consistent national energy policy. It has been quite common to change the rules of Swedish energy policy. It is only recently that national government began to commit itself to promote wind power. Favourable climate for wind power development is now partly established by investment support but policy instruments with time limits prevent strong investment on it. Both wind developers and financial society are rather reluctant to invest on wind projects in this situation.

In addition, there is a lack of coordination between different levels of government. For this reason regional and local government response to wind power remains slow in spite of recent national government commitment.

Sweden has a tradition to seek to utilise environmental resource without disturbing natural landscape. Land use planning has played an important role for both utilising and protecting natural environment, but it has been a barrier for wind power installation. In order to make use of natural environment including wind resource it is necessary to consider also other land use purposes, which has proved negative to wind turbine installation.

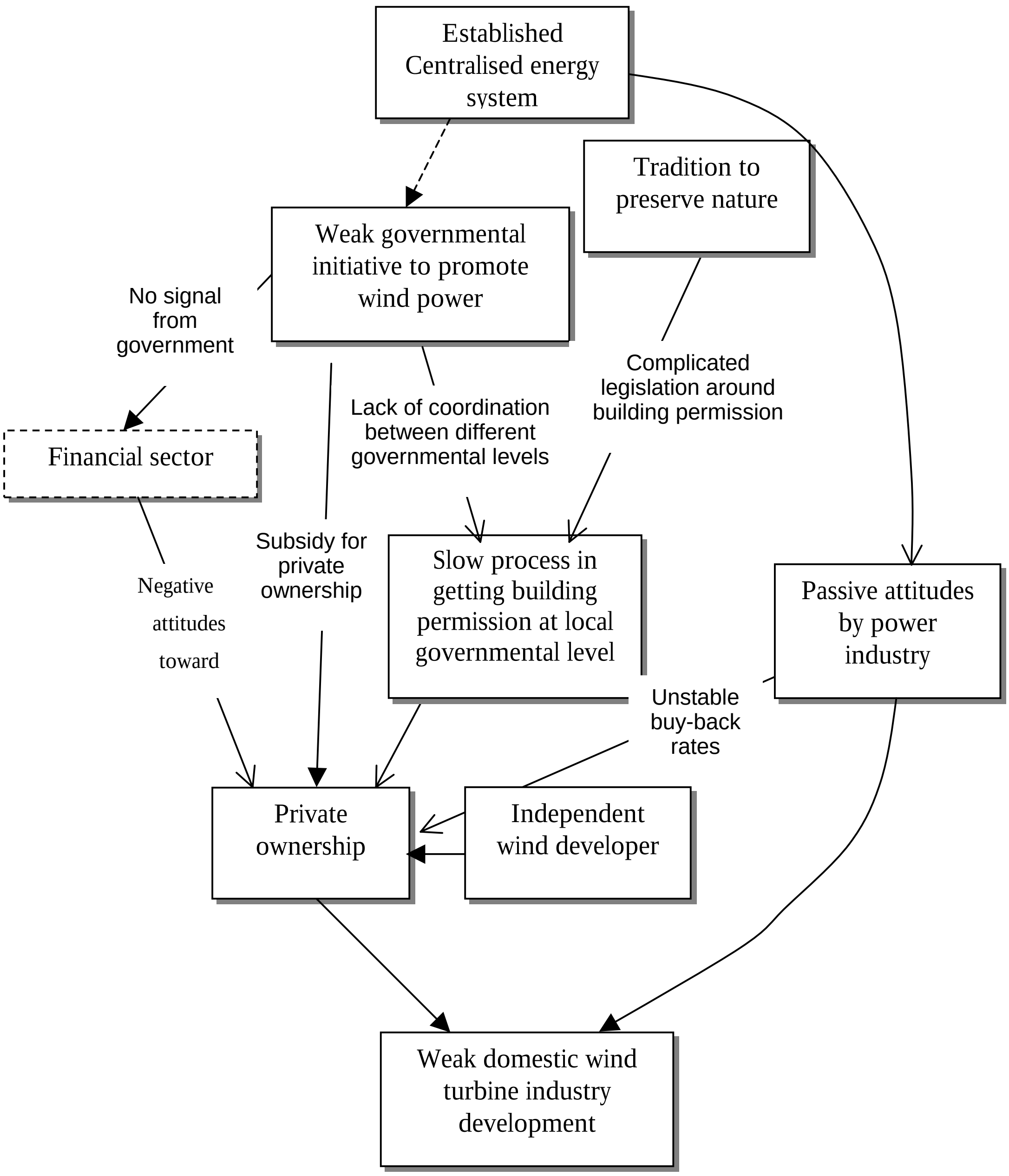
It is communes and regional authorities that have the responsibility to give permission for building wind turbines together with planning of land use. It seems, however, that they are not yet ready to respond to the recent growing demand for wind turbine construction. Because of complicated legislations and permission application procedure and negative response of local government it takes long time to get building permit for wind turbine. This is one of big factors to prevent rapid wind power development in Sweden.

It is understandable that wind power is not yet part of current investment strategy of the power industry. They are not urged to invest in wind energy from supply problems. Present low electricity price because of overcapacity in supply system prevents them from investing in new system including wind power. Neither rules that guarantee long-term return on investments is not established.

The only driver for them to develop wind power is consumer demand and the “Green” movement by consumer has been partly played important role in wind power development. It has been private persons (households and farmers) who have invested their private money in wind power and created the market for the wind power industry.

Figure 4 illustrates the main aspects that have influenced the wind power development in Sweden.

Figure 4 Structure around wind power development in Sweden



6.3 Comparison of the two cases

Next sections will be dedicated to compare the Danish and Swedish policies to elucidate main drivers and barriers for wind power development. Differences and similarities are compared at several levels, i.e. legislation, national government commitment, supporting instrument, energy sector, industry perspective (both power supply and wind turbine perspective), consumer perspective and others. Table 4 gives an overview of rest of this chapter.

Table 5 Summary of findings

	Denmark	Sweden
Legislation	- Spatial planning - No building code - Certification system	- Land use planning - Complicated building code Difficult to get building permit
National government commitment	- Consistent support for wind energy development - Clear target	Inconsistent energy policy lead unreliable wind power policy - No clear target
Supporting instrument	- Effective supply-side policy Investment subsidy (ex): 30% Production subsidy: DKK 0.37/kWh Feed tariff system: 85% of electricity Replacement programme (ex) R&D support: DKK 29.56 million (1998) - Demand-side (to-be-introduced)	- Partly effective supply-side policy Investment subsidy: 15% Production subsidy: SEK 0.171/kWh Feed tariff system: SEK 0.25/kWh R&D support: SEK 46.8 million (1998-2001) - Demand-side (not official green electricity system)
Electricity sector characteristics	- Fossil fuel dependent - High electricity price (DKK 1.28 /kWh, 1998) - Share of wind power in electricity supply system: 8.6% (1998)	- Hydro and nuclear dependent - Cheap electricity price - Share of wind power: 0.2% (1998)
Industry perspective : Wind turbine industry	Strong wind turbine industry based on agricultural manufacture tradition	Young industry
: Power industry	Interest in R&D perspective	Interest in large-scale machines
Consumer perspective	-	Demand for green electricity from corporate customer is high but not from ordinary household
Others	- Strong tradition of wind guild - Climate issue as driving force	- Wind co-operative - No driving force from climate issue perspective

6.3.1 Legislation

The framework of environmental legislation is rather similar in both countries. Both Sweden and

Denmark have objective to protect environment and to utilise natural resources without damaging environment. Land use planning has played an important role in both countries.

Although the objective is the same, Danish legislation is rather simple while the Swedish one is complex, particularly concerning wind power installation. In Sweden wind turbine installation is treated as other building construction. As the result different regulations are applied in the same wind turbine construction. NRL and NVL are the main legislations to consult. Besides wind power is not necessarily considered as environmental benign energy source. Installation of wind turbine requires special consultation with related legislations mainly from environmental protection perspective. Even it is classified in an Ordinance to Environmental Code as something dangerous for the environment. This position in legislation hinders wind energy from gaining local government approval for building permit. It needs consultation with several legislations in different government levels and it takes long time for acquiring building permit. Complicated legislations are one of the major barriers to wind power development in Sweden.

Currently Swedish land use planning has no specific consideration for optimal wind resource utilisation. It puts rather heavier emphasis on other interest such as landscape protection than wind resource utilisation. Thus land use planning has been preventive factor for wind power development in Sweden.

On the other hand in Denmark consultations from environmental perspective are simplified. One act, Environmental Protection Act, covers almost all environmental considerations in Denmark. Installation of land-based wind turbine did not require specific permission in terms of building codes except specified areas. Previously environmental assessment from environmental protection perspective was not required. Today turbines tend to be installed in clusters or in wind farms and environmental assessment is required for those constructions. It surely has facilitated previous installation of land-based individual wind turbines. Instead of building permission regulated by building code Danish wind turbine has to meet a type approval which certifies turbine design. As this certification system has been developed jointly by the authority, manufacturers, users and financers it was easy authority to detect the shortcomings of turbines and manufacturers to modify the designs. It has been played important role in improvement and better performance of wind turbines. This is distinguishing feature of Danish legislation. It helps improvement and facilitating installation of wind turbines instead of hampering it.

Spatial planning in Denmark also influences wind power development positively. It is designed to facilitate optimal utilisation of limited wind resource. In its Act on Spatial Planning different interests including nature protection and land use in general are settled for rational use of wind resource. Spatial planning in Denmark has contributed in optimal use of wind resource and promoting wind power development involving power industry in national policy.

6.3.2 National government commitment

In Denmark wind power has been explicitly mentioned in its energy policies as a mean to promote sustainable society since 1980s. There have been four energy policies since 1980s and specific targets for each policy have been changed. In 1980s it was security of supply with environmental considerations, in the first half of 1990s sustainable development in energy sector and in the second half of 1990s CO_2 reduction. The government commitment, however, on wind power development has been continuously maintained with clear goals to achieve with regard to capacity of wind power. In fact the goals has been fulfilled. The government commitment has not changed even under current electricity market liberalisation which could affect negatively to wind power. This aspect is particularly crucial in Danish context.

Denmark has been successfully promoting environmental benign energy sources under regulated electricity market. It was successful because the government could control energy supply system centrally. It was partly possible because of high electricity price. Danish Government has, however, still strong initiative to promote renewable energy sources including wind power further under current electricity market deregulation process. This clear message from the Government removes uncertainty on future policy around wind power including supporting system. Danish financial sector has been ready to support wind projects. Power industry has been also involved in wind power installation through strong government initiative. It was through agreements between power industry and the Government to install certain capacity of wind power and CO_2 emission reduction target from electricity sector.

In Sweden, on the contrary, wind power was not clearly defined in the energy policy. Since 1980s energy policy itself has been developed rather inconsistently. Although environment consideration has been included in energy policies it was not regarded as main concern. To think retrospectively priority in energy policy has been nuclear issue since the parliament decision on nuclear phase out in 1980. Nuclear debate within the parliament politics has made Swedish energy policy schizophrenic. Disagreement between parties and even within the party brought about unreliable energy policy with frequent changes.

Since 1991 through Energy Policy Bill energy policy was allocating additional resources to facilitate the transformation of the energy system, i.e. to facilitate the phase-out of nuclear power and to improve the environmental characteristics of the energy system, with an emphasis on environmentally acceptable electricity production. There has been, however, no governmental commitment on wind power development so far. No official target concerning neither capacity nor generation is set. Intention of the Government with regard to wind power development is particularly unclear under deregulated market. It has not clarified its stance. It can be concluded that, so far, no consistent wind power policy exists in Sweden. Although not a less amount of resource has been allocated because of political uncertainty that has characterised Swedish energy policy, market actors, particularly in financial sector, are still unwilling to enter the wind power market. They are unsure about the duration of the supporting system to promote renewable energy. Unclear signals from the government have kept many market actors from investing on wind power. So far governmental policy does not involve power industry.

6.3.3 Supporting instrument

Supply-side incentives are not so different in the two countries. They are investment subsidy, production subsidy and guaranteed market for wind generated electricity. However, what makes a difference is their management in both countries.

In Denmark investment subsidy was introduced in 1979 and was abolished 10 years later when the effect became clear i.e. development of wind turbine industry and fall of wind turbine price. On the other hand in Sweden the budget is set for 5-year period. This implies the subsidy programme expires at 2002 June irrespective of the results. This fixed time limit setting from the beginning deprives flexibility of the programme.

Due to the transition from regulated to liberated market Denmark is currently changing rules of its subsidy scheme related to wind power. As for buy-back rates it had been fixed as 85% of conventional electricity price since 1993. After 2000 a settlement price has been introduced. One of the production subsidies, which used to be paid based on actual production, now is given according to hypothetical load hours during transition period. This system will be changed when new green certificate system is introduced after 2003. In Sweden both production subsidy and buy-back system are unstable. The rule of former is only effective by the end of 2000. The latter depends on two factors i.e. administrative cost and profit of concession holder. Wind turbine owners are uncertain about the price of wind-generated electricity. Not to mention the low level of rates this fact is definitely hinders potential wind turbine owner from buying it. It should note previous stable subsidy scheme in Denmark had been constantly helped wind power development and contributed its market penetration. On the other hand wind power in Sweden has never benefited from stable support.

As demand-side incentive, both countries are expecting to introduce green certificate system in 2003. The commitment to the system is, however, different in both countries. Denmark is more advanced and prepared than Sweden in that it has clear target of achieving 20% of RE electricity. At the moment it is unclear if Sweden intends to realize certain share of RE electricity. Because of the uncertainty around green certificate system market actors are not eager to participate the market in Sweden. On the contrary Danish power industry and wind power producers are certain about Government intention and thus ready to participate the system.

6.3.4 Energy sector

The features of the energy sector in Denmark and Sweden differ sharply. First, main supply source for electricity is different. In 1998, 94% of Danish electricity comes from fossil fuels of which coal is 65%, natural gas 15%, oil 14%[106]. In Sweden the situation is completely different. Main electricity sources are hydro and nuclear power. Each holds nearly 50% of total electricity supply. They are carbon free supply source at least during power production phase. Thus the pressure from current climate change issue is critical in Denmark. It has been committed itself to reduce CO_2 emission since 1996 by restructuring electricity supply system. So far climate change issue does not push Sweden to alter current electricity system.

Different supply systems imply different electricity price. Total price of electricity to the customer consist of cost for electricity generation, network tariff and charges and taxes. Electricity generation cost is generally higher in Denmark. Unit cost of generation plus network tariff is DKK 0.455/kWh in Denmark. In Sweden generation cost is SEK 0.04/kWh for hydropower, SEK 0.07/kWh for nuclear and network tariff is around SEK 0.21- 0.42[107]. The major discrepancy comes, however, from different tax and charge levels. In Denmark electricity tax (DKK 0.46/kWh), CO_2 tax (DKK 0.1/kWh), SO_2 tax (DKK 0.009/kWh) and 25% VAT is added on top. The average customer price was DKK 1.28/kWh in 1998[108]. In Sweden electricity tax (SEK 0.151/kWh) and 25% VAT is charged. Corresponding customer price of electricity is around SEK 0.752- 1.068/kWh depending on consumption level. Table 5 summarises the components of electricity price for normal consumer in both countries.

Table 6 Electricity price in Denmark and Sweden

	Denmark (DKK/kWh)	Sweden (SEK/kWh)
Variable generation cost	0.455	0.04 (hydropower)/0.07 (nuclear power)/0.05-0.13 (CHP)
Network tariff		0.21- 0.42
Electricity tax	0.46	0.151
CO2 tax	0.1	-
SO2 tax	0.009	-
VAT (%)	25%	25%
Total	1.28	0.752- 1.068

[106] Calculated from Danish Energy Agency. (1998a). *Energy statistics 1998*.

[107] STEM. (1998). *Swedish Electricity Market 1998*. pp.16, 19.

[108] IEA. (2000). *IEA Wind Energy Annual Report 1999*. p.55.

The level of price is intentionally maintained in both countries. In Sweden it has been Governmental policy to keep electricity price low since 1970s from social perspective. On the contrary in Denmark fiscal purpose was rather strong[109]. These backgrounds influence deeply the condition of wind power development. Relatively high electricity price enabled wind power to be competitive before too long in Denmark. Swedish cheap electricity price has been decisive factor for wind power development. Owing to cheap price priority in wind power research has been put on development of cost-efficient turbines, which so far has not been so successful.

6.3.5 Industry perspective

Danish wind turbine industry has its background in agricultural machinery manufacturing. They had technical knowledge in manufacturing machines. This was an indispensable advantage because they knew what is required in practical terms.

They were inspired by large-scale Gedser Wind Turbine installed by a power utility earlier. They saw big possibility in wind turbine market and launched new business in 1970s. They were fortunate in that they had the model, Gedser machine, to learn its limitations. Their focus has been practical usage perspective. They started from small-scale turbines and gradually increased the size when they saw market demand and technical possibility. Since its establishment there has been constant demand for its products in domestic as well as foreign market.

Consistent government support from the beginning was no doubt a driver for stable development for wind turbine industry. Government facilitated market development by the reliable installation subsidy scheme. Backed by strong government policy and demand wind turbine industry grew steadily and come to form one of major industry in Denmark.

In Sweden the situation is different. Government policy has not been strong and clear enough to contribute to develop wind power industry. There are only two Swedish wind turbine manufacturers. The possible driving force for wind turbine industry development in Sweden comes from business society. Current trend to restructuring toward decentralised energy system can promote the development of wind power industry.

The background of Swedish wind turbine industry is an engineering consultancy company, manufacturer of railcars and military vehicles. They have enough technological knowledge as they have engaged in R&D programme on wind energy before establishing the company.

Although Sweden lost the opportunity to be the first mover it has one advantage to the Danish

[109] Nielsen, S. Rønsholdt. (2000, September 5). Personal interview.

counterpart. It can learn many lessons and failures from Danish industry and produce improved turbines with efficient performance[110].

Both Danish and Swedish power industry have been deeply involved in national energy policy. As the objective of energy policy is dissimilar the sphere they engaged have been different. The former had initiated wind turbine experiment before the official research programme started and when the programme started in 1970s it has taken part from the beginning. Although its focus has been R&D rather than practical utilisation perspective it also has contributed to install 100 MW capacity in 1992 and another 100 MW in 1992 by agreements with the Government. Third phase of agreement set additional 200 MW by 2000. Besides these land-based turbines power industry has concurred to develop 750 MW offshore turbines by the period from 2001 to 2008. Its role in wind power R&D as well as installation will continue to be important in the future.

On the contrary Swedish power industry has been involved hydro and nuclear power development for long time. Strictly speaking the former had developed by the State Power Board, one department of Government at that time. Today Government initiative in wind power development has not so much influenced strategies of power industry. It does not, however, necessarily mean that they are indifferent to wind power. In spite of the fact that it has enough energy supply source and it is not necessary to exploit alternative energy source except in case of nuclear power plants closure, power industry is still interested in wind power as an option for following reasons. They expect future green certificate system might create market for wind energy and are willing to provide wind-produced electricity when there is customer demand.

Reflecting low price for electricity in Swedish energy supply system their interests have been cost effective technique. They have assumed large-scale machines were more efficient than small-scale ones in the long run. In addition to future offshore development is another factor. These are the main reasons for concentrating large-scale machines from their research commencement.

6.3.6 Consumer perspective

“Green movement” by consumers can be found in both Denmark and Sweden. Its appearance is somewhat different.

In Danish energy system consumer perspective is not particularly referred, as consumers are involved in wind power development through wind co-operative. It is key point in Danish wind power development. With the background of self-organising electricity supply system, consumer demand on environmentally benign electricity contributed to its early development. Later wind co-operative

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110 Dalén, G. (2000, June 27). Personal communication.

organised wind turbine owner association, which represents turbine owners' interests. As of 1997 there are 1500 co-operatives and 100,000 families have shares in local wind turbines. Together with Wind Turbine Manufacturers Association the association has been politically active to improve position of wind power in national energy supply system. Their main achievements are Law for Wind turbine, establishment of insurance company specialising for wind turbines and periodical publication of technical description with owners' satisfaction survey. Through effective lobbying they won the high buy-back rates (85% of conventional electricity price) in the Law for Wind Turbines in 1992.

It is partly true that consumer demand for green electricity including wind-generated electricity has been a driving force for power companies to develop wind power since 1996 in Sweden. It is, however, only corporate customers who demand green electricity at the moment. For them green electricity is necessary for attracting their customers in competitive market therefore it is within their strategy. On the other hand in general household customer does not have such incentive. As they have no need to show their greenness to anyone it is difficult to appeal their own initiative to purchase expensive wind-generated electricity. It is possible to purchase cheap electricity in spot market under current deregulated market.

The establishment of Swedish Windpower Association in 1986 is still one sign of "green movement" by the public. Some members are active as wind developer. This movement in some regions lead household consumers to organise wind co-operative. In Gotland, well-known renewable energy supported island and the most wind turbine concentrated region in Sweden,[111] the first wind turbines were developed by co-operatives. As of 2000 there are around 50 cooperatives with more than 10,000 households as members in Sweden. Compared to Danish counterpart they are still young (only 7 years since first co-operative has established in Göteborg) and small-scale. Although they are active in national wind power policy they are not yet influential on politics as Danish counterpart.

6.3.7 Others

The implication of the climate issue on national electricity supply system differs largely in the two countries. It is the major driving force to restructure fossil fuel dependent system in Denmark. With international commitment the Government is obliged to reduce greenhouse gases from energy sector. By developing wind power it can reduce CO_2 emissions. This is an influential driver to promote wind power development.

Sweden, on the other hand, has no requirement from climate issue as it is based on carbon free electricity system. There was no reason to build wind turbine to reduce CO_2 emission. It has already

[111] Gotland Energy Agency (n.d.). *The sustainable Society: Energy and Environment Projects on Gotland*. Visby: Publicity Announcement Office.

established electricity supply system with affluent quantity and low price. Sweden has, however, its own reason to reconstruct supply system, i.e. the nuclear issue.

Electricity market condition, i.e. deregulated or regulated, has important implication for wind power. Although declining the cost for wind power generation is more expensive compared to conventional thermal power plant for several reasons. Thus wind power cannot be competitive by itself and penetrate in the market. The Danish Government promoted wind power intensively under regulated electricity market. If it were not for regulated market Government could have never ordered power industry to install certain amount of capacity. High electricity price enabled Danish wind turbine industry to promote their early developed but quite expensive small wind turbines in the market.

Swedish electricity system has already liberated since 1996. Naturally in deregulated market expensive wind generated electricity by itself cannot be competitive. And it is impossible for the Government to promote wind power as Danish counterpart had done before. It is possible, however, to support wind power development through clear initiative in green certificate system as Danish counterpart. Under present deregulated electricity market wind power has no chance of gaining market share without government support.

6.4 Concluding comments

Denmark is driven towards a wind power-based society by several factors that Sweden does not have.

Because of geographical condition Denmark has only small share of hydropower. It turned, however, this disadvantage into advantage by developing decentralised energy system. Needless to say, small-scale decentralised energy is favourable from environmental perspective. Sweden has, unfortunately or fortunately, rich water resource. And it developed another large-scale energy source, i.e. nuclear power with strong government commitment. Thus the energy supply structure difference is obvious. At this point Sweden lost possibility to develop decentralised energy system.

So far Swedish Government has not had the strong incentive to promote wind power as the Danish counterpart has, and there is no strong wind turbine industry that the Government need to promote. In Denmark the situation is opposite. Government had incentive to support domestic wind turbine industry constantly from its national economy perspective. Wind turbine industry became significant enough to play an important role in Danish economy. It also supported individual ownership of wind turbine to promote decentralised energy system. In addition to lack of political support, the established Swedish energy system itself have prevented the development of wind power as “new” energy source. Swedish energy system based on hydro and nuclear power is closely related to the core of Swedish industry, ABB. Until recently its stance to renewable energy including wind power was not positive.

Private involvement in wind power development and co-operative or private ownership is gradually increasing in Sweden, but it is not the same strong driving force for wind power deployment as it is in Denmark. Although general attitudes toward wind power are favourable, there are still some people opposing its installation from their particular point of view. It is usually not local people who disagree with localisation of wind turbines. They are those who have summerhouse in the vicinity and their view will be disturbed by wind turbine. And they often are highly educated (lawyers, doctors and civil servants) who know how to appeal[112] and delay the project.

[112] Wizelius, T. (2000, August 4). Personal communication.

7. Discussion: Can Sweden Learn from the Danish Experience?

Reflecting what have identified in previous chapters this chapter will consider whether Sweden can learn some lessons from Denmark after all. The focus is to seek the potential for Sweden to increase wind power. Specifically it will try to answer the question if Sweden can get more benefit from wind power development than current situation.

In order to extract key issues in wind power, SWOT analysis will be carried out. Based on SWOT analysis and key findings from primary data (Table 1), three key issues, i.e. climate issue implications, pricing of electricity considering environmental impacts from production and demand for environmental benign electricity are identified.

7.1 SWOT Analysis

SWOT represents strengths, weaknesses, opportunities and threats. As strengths and weaknesses focus on those of technology itself, they will be discussed in a general sense. On the other hand opportunities and threats are those related to other technologies, legislations, background of energy sector and other situations thus they will be discussed in Swedish and Danish context.

7.1.1 Strengths and weaknesses

The technology of wind power has the advantage to conventional power generation in that it does not emit any atmospheric pollutant including CO_2. It is cleaner than other technology. It is also non-depletable and thus no fear of exhausting, which is one of the problems in fossil fuels.

On the other hand, compared to other thermal power, the unit size of wind power is smaller. It means if it were to replace one thermal plant the number of unit has to increase. Its cost of generating electricity is higher than that of conventional power plant. Because of its intermittent nature it cannot serve as base load in energy supply system. Visual and noise disturbance is also weakness of wind power.

7.1.2 Opportunities and threats

The largest opportunity for wind power in current situation is the climate issue. As it does not emit CO_2 it holds advantage to other carbon based fuels in the climate change discussions. For Denmark wind power offers opportunity. Danish electricity supply system is dependent on coal-fired plants, which is main source of CO_2 emission of the country. By increasing wind power Denmark can achieve CO_2 reduction target. Other opportunity is that it has offers potential for farmers and groups of people to purchase turbines. In Denmark favourable loans are offered to private individual by the financial sector.

One threat for Danish wind power is deregulation of electricity market. Wind power had enjoyed generous support from the state since 1980s. In liberated market it is not possible to support wind power deliberately. Loss of subsidy in competitive market is a threat for wind power. This threat can be translated into lower electricity price at spot market at Nordic power pool system. When the electricity market is completely opened expensive wind power generated electricity can hardly compete with less expensive electricity from hydropower in Norway or Sweden.

As Swedish electricity supply system is basically carbon free nuclear and hydropower the climate issue does not imply the same opportunity for Swedish wind power as it does for Danish counterpart. It still gives an opportunity for Sweden to counter international pressure to reduce greenhouse effect. Although it is not urgent as Denmark, Sweden also has to build carbon free new power plant when it closes down nuclear power plants in future. EU directives to promote renewable energy source is other opportunity[113]. And wind turbine offers export possibilities[114] thus can contribute to national economy. The major threat for wind power in Sweden has been complicated legislations for getting building permit[115]. Because of complex legislation over different government levels it takes long time until wind developer can start constructing turbines. There is also threat from investment point of view. In Sweden wind project are not considered as investment worth while supporting by the financial sector. Another threat is competition from other renewable energy sources including biomass. Sweden has rich forest resource and forest and related industries are one of major industries in Sweden. In industry electricity production from biofuels has been steadily increasing since 1980. As of 1998, it supplies as much as 2.5TWh[116]. Even though it is within industry it has large potential to increase the share in electricity production and thus is threat to wind power.

7.2 Climate issue implications

Previous chapter has clarified that strong government commitment is critical in wind power development. And from brief analysis in the preceding section, a key point that is critical in wind power development is climate change issue. Particularly Kyoto protocol that binds industrialised countries to reduce CO_2 emission is important.

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113 Dalén, G. (2000, June 27). Personal communication.

114 Göransson, B. (2000, August 24). Personal communication.

115 Dalén, G. (2000, June 27). Personal communication, Göransson, B. (2000, August 24). Personal communication and Wizelius, T. (2000, July 30). Personal communication.

116 STEM. (1999b). *Energy in Sweden. Facts and figures 1999*.

Denmark has promised to reduce its greenhouse gases including CO_2 emission 21% compared to 1990 levels during 2008-2012[117]. Denmark has chosen to achieve the target by introducing CO_2 quotas for electricity production[118]. According to the Bill on CO_2 Quotas for electricity production, all electricity producers in Denmark are allocated CO_2 quotas[119]. Total CO_2 quotas during 2000-2003 are: 23 million tons in 2000, 22 million tons in 2001, 21 million tons in 2002 and 20 million tons in 2003. To ensure cost-effectiveness it is up to each producer to choose the method to achieve the target. The part of emission permit that has not been used within one year may be used forward to the following years. It has possibility of development into international tradable permit system. Since 1997, building of the new coal-fired power plants was forbidden in Denmark[120] and it is only wind power that can achieve the target cost-effectively. Therefore it is quite natural that wind power is developed in accordance with CO_2 reduction target.

On the other hand agreement within EU after Kyoto Conference allowed Sweden to increase greenhouse gas by 4% for the period 2008-2012. At the moment Kyoto protocol does not urge Sweden to change energy system. In the short perspective there is no pressure from it. In the long run, however, EU as a whole it has to be decreased by 40%[121]. In the longer perspective it serves as driving force for alternative energy development in Sweden.

As identified in previous section not only wind power but also biomass is considered as promising renewable energy resource. Sweden is rich in forest resource. Biofuel and peat had 92 TWh supply in total energy supply of 480 TWh in 1998[122] and it is said that potential of biofuel is as much as 130-150 TWh in 20 years[123]. The advantage of biofuel is that it can generate not only power but also heat and power simultaneously. As Sweden has high heat demand because of geographical condition, it has been national interest to support the development. Sweden has also leading position in both utilising and know-how accumulation concerning biomass in international aspect[124]. As other countries started

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117 Danish Energy Agency. (n.d.) *Facts and Vision. Danish Policies and Measures to Combat Climate Change.*

118 Danish Act on CO_2 Quotas for Electricity Production (Act no. 376 of 2 June 1999).

119 CO_2 free or CO_2 neutral energy producers are exempted.

120 Danish Energy Agency. (1998b). *Report concerning Danish energy policy.*

121 STEM. (1999c). *Energimyndighetens arbete med omställningen av energisystemet*, p.11.

122 STEM. (1999b). Energy in Sweden. Facts and figures 1999.

123 STEM. (1999c). *Energimyndighetens arbete med omställningen av energisystemet*, p.33.

124 STEM. (1999c). Energimyndighetens arbete med omställningen av energisystemet, p.33.

to develop biomass in order to achieve Kyoto protocol[125], there is a new market for biomass technologies and products. Swedish forest and related industry has an opportunity for to gain market share in European market. In this way Swedish biomass has advantage in its rich resource availability and established knowledge on usage and technology. It has a possibility of exporting the technology to other countries as well.

On the other hand advantages of wind power is weaker than those of biomass. Resource availability is not as high as biofuel due to historical lack of governmental initiative. Swedish wind turbine industry is young and its possibility of exporting its products and gaining market share is at the moment limited.

7.3 Right price for electricity

The economics of wind power is another important issue. As identified from several interviews wind power is considered expensive compared to other conventional electricity production system. However, new source has to be developed before more nuclear power is phased out. Considering that hydropower is not allowed to exploit, possible new sources are wind power, fossil fuel or biofuel based power. Discussions below exclude import of electricity since it is out of control of the Government.

This section will try to assess the competitiveness of wind power through internalisation of externalities by introducing several environmental taxes in electricity production. Since 1991 CO_2 tax has levied on carbon content of various energy in Sweden. The rate has been gradually raised. As of 1999 it amounts to 37 öre per kg of emitted carbon dioxide. In the same year of CO_2 tax introduction, sulphur tax was and in the next year NO_x charge[126] was introduced[127]. Table 7 shows the changes of CO_2 tax rate over time and others. At the moment fuels used for electricity production is exempted from these taxes. This does not mean, however, that it has no influence on wind power. If the CO_2 tax, sulphur tax and NO_x charge that aims to reduce these emissions from electricity production were introduced, there will help wind power to be more competitive against the polluting sources.

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[125] United States, France and Germany are interested in developing biomass (STEM. (2000). *Strategier för att minska koldioxidutsläppen. En studie av några Annex 1-länder* [Strategies to reduce carbondioxide emission. A study of some Annex 1 countries]. Eskilstuna: Swedish National Energy Administration, pp.87, 94, 100).

[126] Large combustion plants that have a power input over 5MW and an energy output over 25GWh a year are covered by NOx charge. All the plants selected below fall in this category.

[127] It is said that the level of both sulphur tax and NO_x charge is set to reflect the external cost of their emissions (Swedish Environmental Protection Agency. (1997). *Environmental taxes in Sweden --- economic instruments of environmental policy*. Stockholm: Swedish Environmental Protection Agency, p.15), but it is plausible to interpret that it is set in order to achieve reduction target, rather than is based on social cost.

Table 7 CO_2 tax, NO_x charge and sulphur tax in Sweden

	CO2 tax (öre/kg)	NOx charge (SEK/kg)	Sulphur tax (SEK/kg)
1991	25	40	30
1993	32		
1996	36		
1997	37		

Source: Swedish Environmental Protection Agency. (1997). *Environmental taxes in Sweden --- economic instruments of environmental policy*, pp.24, 31, 42.

In Table 8 emission factors for CO_2, NO_x and sulphur are indicated. Those of coal, oil and natural gas are calculated according to SOU 1995: 140 and that of biomass is calculated from Swedish Government. (1997)[128].

Table 8 Emission factors for CO_2, NO_x and SO_2 per kWh in Condensing power and CHP

	CO2 g/kWh	NOx g/kWh		S g/kWh	
Fuel type		Condensing power	CHP	Condensing power	CHP
Coal	341	0.11	0.185	0.11	0.185
Oil	271	0.107	0.178	0.107	0.178
Natural gas	202	0.108	0.181	-	-
Biomass	96	-	0.182	-	-

Source: Coal, oil and natural gas are calculated from SOU 1995: 140, pp. 45, 52 and biomass is calculated from Swedish Government. (1997). *Sweden's Second National Communication on Climate Change*, p.163. Conversion factors are taken from STEM. (1999b). *Energiläget 1999* [Energy in Sweden 1999], p.36.

Table 8 shows the total production cost with estimated tax of selected power plants with fuel types. Production cost includes both investment cost and variable cost. As this thesis is based on the fact that nuclear power is to be closed down in the future, it is important to include investment cost to focus on replacement of nuclear power[129]. With these figures it is possible to calculate hypothetical tax rate for CO_2 and NO_x charge and sulphur tax and get the "right" price for electricity production. Although limitation that these are data from existing plants and technology development will change these figures in the future exists, it is possible to estimate the amount of tax and charges for each plant. In the last row the calculated production cost including tax and charges are shown. For reference, the

[128] The emission level of NO_x and sulphur (SO_2) is highly dependent on technical aspects of the plants (the kind of desulphurisation instruments, efficiency, etc). The calculation below does not go into detail, as the purpose is to overview approximate charge and tax level for comparison.

[129] Usually only variable cost that only cover maintenance and operational cost is compared, but this is not appropriate in this context.

price for wind power is **28- 33 öre/kWh** without any subsidies[130], a price which is comparable with prices in the last low of Table 8.

Table 9 Electricity price with taxes

	Condensing power			Combined power and heating plant			
	Conventional steam cycle		Combined cycle	Conventional steam cycle			Smoke gas condensing
Fuel type	Coal	Oil	Natural gas	Coal	Oil	Biofuel	Biofuel
Production cost (öre/kWh)	33	32	29	26	23	46	39
CO2 tax (0.037 öre/g)	12.6	10	7.5	12.6	10	3.6	3.6
NOx charge (4öre/g)	0.44	0.43	0.43	0.74	0.71	0.73	0.73
Sulphur tax (3öre/g)	0.33	0.32	0	0.56	0.53	0	0
Total (öre/kWh)	46.4	42.8	36.9	39.9	34.3	50.3	43.3

Note: Electricity price is taken from SOU 1995: 140, pp. 42, 44.

When fuel used in electricity generation is payable to current rate of CO_2 tax, NO_x charge and sulphur tax, cheap CHP with coal and oil cannot compete wind power. With these taxes wind-generated electricity is competitive against power generated from all these CO_2 emitting fuels. The competitiveness of wind power is obvious against biofuel-based plant which identified as promising in previous section with related tax and charge.

When electricity production gets right price by utilising plant specific data (full lifecycle data) the comparison with the wind power is more distinctive[131]. The emission data that is used to calculate emission factors cover not only operational and maintenance cost but also transportation of fuel to the plant. Thus following example steps further to full internalisation of externality of electricity production. The tables below show the emission factors and electricity price including tax and charge[132].

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130 STEM. (1998). Swedish Electricity Market 1998, p.16.

131 The data is obtained from Vattenfall, one of the largest electricity producers in Sweden.

132 The validity of data was verified by comparing similar data from Sydkraft, other largest electricity producer in Sweden.

Table 10 Emission factor per kWh of selected Vattenfall's facilities

	Oil condensing power	Gas turbine power	Natural gas combined cycle	CHP (biofuel gasification)	CHP with Biofuel (steam cycle and smoke gas condensing)	Wind power
CO2 g/kWh	682	986	387	424	330	0.0607
NOx g/kWh	0.461	3.08	0.068	0.213	0.181	0.000139
SO2 g/kWh	0.461	0.667	0.00272	0.17	0.033	0.000152

Source: Compiled from Brännström-Norberg, Britt-Marie. et al. (1996). Livscykelanalys för Vattenfalls elproduktion. Smmanfattande rapport [Life cycle analysis for electricity production in Vattenfall]. Stockholm: Vattenfall.

Table 11 Electricity price with taxes (2)

	Oil condensing power	Gas turbine power	Natural gas combined cycle	CHP (biofuel gasification)	CHP with Biofuel (steam cycle and smoke gas condensing)	Wind power
Production cost	31	42	29	75	44	28-33
CO2 tax (37 öre/kg)	25.2	36.5	14.3	15.7	12.2	0
NOx charge	1.8	12.3	0.3	0.9	0.7	0
Sulphur tax	0.7	1	0.0	0.3	0.1	0
Total (öre/kWh)	58.7	91.8	43.6	91.8	57.0	28-33

Note: Electricity price is taken from SOU 1995: 140, pp. 42, 44.

As the result of transportation of fuel, emission factors increase at all of the plant and this leads higher CO_2 and NO_x charge and sulphur tax levels.

It is now clear that compared to the CO_2 emitting fuels, wind power is more competitive when the price reflects also external costs.

7.4 Demand for green electricity

The discussion of the previous section showed that "expensive" generation cost of wind power is actually not expensive when most of the external cost of producing electricity is internalised by tax and charge. In this section the approach from demand side to the same issue is attempted. Consumer behaviour is other part of decisive factor in deciding electricity balance. As summarised in section 6.2.6, consumer demand on green electricity can be a promoting factor in wind power development.

In economic term consumer's preference can be measured by willingness to pay (WTP) for a good. Thus demand for wind power can be assessed by asking people how much they are willing to pay extra for wind generated electricity. Although there is a gap between what they rely in questionnaire (attitude) and how they act (behaviour)[133] it shows partly consumer's preference.

As shown in section 6.3.4, in Sweden the electricity price for normal consumer is SEK 0.752-1.068/kWh of which variable generation cost accounts SEK 0.04- 0.13/kWh. On the other hand if it is replaced by wind power generation cost is SEK 0.28- 0.33/kWh[134]. With these figures it is possible to calculate hypothetical electricity price of 100% wind power. That is SEK 0.992- 1.268/kWh. It is 22- 27% higher than the actual electricity price.

One study made interview through telephone to selected consumers and asked among others, if they are prepared to pay extra for renewable energy[135]. Around 60% of respondents replied that they were willing to pay extra for both heating and electricity. The table below (Table 11) illustrates the percentage of respondents compared to the total who replied as willing to pay more cost of 5%, 10%, 20%, 50% and 100% respectively.

Table 12 Share of WTP for heating and electricity at different extra costs

Extra cost	Heating (%)	Electricity (%)
Not specified	57	61
5%	36	46
10%	34	44
20%	20	29
50%	6	11
100%	3	5

Source: Frankel, H, Ling, E. and Lundgren, K. (1996). *Bioenergins unvarande och framtida konkurrenskraft – tre djupstudier inom förädlingskedjan* [Bioenergy, its present and future competitiveness – multidisciplinary study]. Lund: International Institute for Industrial Environmental Economics, p.195.

The price increase by wind power falls between 20- 50% in this table. Thus even price increases by 22-29%, 11- 29% of the consumers are still willing to pay. Although this calculation is arbitrary and it is not fair to ask consumers their WTP for wind power now (because it is in the future when nuclear power be partly replaced by wind power, it is fair to compare wind power and other source in the future) it indicates possibilities for wind-generated electricity to gain customer.

Presently energy industry is searching for possibilities to sell green electricity. They are, however, not

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133 Holt, E. A. (1997). *Green pricing resource guide*. http://www.rapmaine.org/gpguid/gp_guide.html [2000, September 15].

134 This is only an assumption that wind power replaces the entire energy source for discussion. In reality it is impossible for wind power to take place of it.

135 Frankel, H, Ling, E. and Lundgren, K. (1996). *Bioenergins unvarande och framtida konkurrenskraft – tre djupstudier inom förädlingskedjan* [Bioenergy, its present and future competitiveness – multidisciplinary study]. Lund: International Institute for Industrial Environmental Economics, pp.189-198.

yet sure how much customers are willing to pay extra for it. Because of this uncertainty the price difference between ordinary and green electricity for private customers is small (around 0-5 öre/kWh) according the brief survey.

Contrary to private customer corporate consumers are more prepared to pay extra for green electricity. Several energy companies replied in the questionnaire that the number of corporate customers who ask about green electricity and actual purchase of it is expanding since it started to offer the service in 1996[136]. Well-known example is Swedish Railway who is one of the largest electricity consumers in Sweden[137]. Although the eco-labelled electricity it buys is produced from hydropower, the possibility of wind power to gain corporate customers is high. Several energy companies expect the market for green electricity among corporate customers is more promising than among private customers. According to Swedish Society for Nature Conservation who certifies "green electricity," sales of green electricity has risen 6% to 6.8 TWh[138].

Demand from consumers has been a driving force for suppliers to invest wind power in Sweden but it is not yet widely accepted as in Denmark where consumer involvement in wind power development has been a key point. As clarified in previous chapters consumers in Denmark are engaged in its development from early stage and their wind power have been supported by the state through generous subsidies. In addition the price level of electricity has been kept high through taxes. So there have been fewer problems for consumers to accept high price of electricity even without environmental concern. On the other hand in Sweden low price level of electricity is a constraint for consumer's environmental awareness to promote wind power development.

7.5 Possibility of Wind Power Development in Sweden

This section will try to answer the question "what can Sweden learn from Denmark?" Lessons can be interpreted both actively and passively.

7.5.1 Lessons

Sweden shares several characteristics concerning wind power with Denmark. Thus there is the opportunity of wind power to germinate. First of all, Sweden has also wind co-operatives that has played important role in Danish wind power development. Although it is still young and small-scale it

136 Bergström, U. (2000, September 18). Telephone interview, Nicklasson, U. (2000, September 20). Personal communication and Skarp, S. (2000, September 20). Personal communication.

137 SJ. (1999). *Environmental Performance Report. The SJ Group 1999.* Gälve: Statens Järnvägar, p.15.

138 Swedish Society for Nature Conservation. (2000).

is possible that its influence will increase in the future. Danish experience shows that constant encouragement by the Government is crucial. They could not have been influential enough alone. Swedish wind co-operative and private ownership need constant governmental support as Danish counterpart had enjoyed.

It is obvious that it is consistent political support that have crucially lacked in Swedish wind power policy. Reliable policy toward private ownership, turbine investment and high buy-back system is essential. Until recently Swedish Government was not active in wind power development. Since 1998, however, Government (Swedish National Energy Administration) has started to initiate wind power development. In order to carry out effective policy Energy Administration can draw many lessons from Danish counterpart. All governmental support including subsidy schemes, buy back system and R&D programmes, should be consistent and reliable for long period of time. Clear signal from the Government create favourable climate for wind power investment. Presently investors are reluctant to invest on wind power project because they are uncertain about the duration of supporting system.

In addition to installation subsidy, private individual still needs financial support to invest on wind turbines. Clear governmental target such as to achieve certain percentage of wind power in the electricity market or more specifically in certain region will affect attitudes of financial society positively to wind project and turn them to finance the projects.

In Danish wind power system power industry has been involved party through strong government initiative. So far governmental initiative does not influence decision making of Swedish power industry. It is true that it is not possible to force power industry to install wind turbines in Sweden where the electricity market is liberated but reliable governmental policy can influence their future investment strategy.

As for demand-side policy, i.e. green certificate system, also unambiguous government initiative is necessary for successful implementation. Although Denmark has not yet launched this system Sweden can see its target setting with clear objective. Consistent policy with clear target is always required.

Market creation is important for domestic wind turbine industry development. Government can arrange favourable conditions for its development through efficient space planning. Current complicated procedure to get building permit can be modified through strong initiative to promote localisation of turbines. This can be done by establishment of official target and break it down to regional and local (community) targets.

7.5.2 Limitations

Previous section pointed out several lessons that Sweden can learn from Denmark. There are, however, still some aspects that keep it from applying everything to promote wind power development.

The largest point that distinguishes Danish from Swedish system is existence of nuclear power[139]. It is impossible to apply what is effective in nuclear free society into nuclear dependent society. For example, CO_2 emission reduction target has been quite effective in promoting wind power in Denmark. Same policy does not work in Sweden. Clear target based on other issue has to be addressed in the latter.

When the second oil crisis hit the world, the reaction of Denmark and Sweden was similar, i.e. to seek the way to reduce fossil fuel import and dependence on them. The situation in terms of electricity supply system was, however, not the same in both countries. Danish system was more dependent on oil (18% of electricity generation[140]) than Swedish system (10%[141]). Sweden was on its way to the nuclear dependent society and fossil fuel dependency was naturally decreasing. After the accident in Three Mile Island nuclear issue has practically become a central concern in Swedish energy policy. Then fossil fuel dependent Denmark has intensively started to develop wind power. Nuclear power was already so involved in Swedish society for long time that there is too much interests around. The parliament politics is not an exception. Disagreement between political parties has paralysed reliable energy policy since 1980s. It is still major issue to be discussed in Swedish energy policy. Compared to nuclear power issue wind power is only one of the many other matters.

One of the reasons the Government could not carry out energy policy is variable political decision. It is quite often in Swedish politics to change rule of the game. This creates unstable policies in many fields including energy. It is contingent on political backgrounds whether or not political consensus to maintain reliable policy on certain topic can be reached. In Denmark it was possible for different political parties to agree on wind power policy. Judging from previous political disagreement on nuclear issues it seems it is difficult for political parties to do the same in Sweden.

Secondly different wind power economics exist in Sweden and Denmark. Private involvement in Denmark have contributed to great extent in wind power development in Denmark at the same time it has negative aspect of highly subsidy dependent wind power. Danish society is paying high cost to support expensive private owned wind turbines. There is no need to discuss externalities of electricity production to support wind power because it is already supported from other reasons. On the other hand in Sweden there is no political support for wind power and the price level of electricity is low. Therefore it is necessary to justify it by bringing externality issue. The previous section tried to defend wind power from internalising externalities based on assumptions. The reality is that wind energy is considered expensive because it does not get right price.

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139 This is closely related to existence of domestic nuclear industry, which will be addressed later in this section.

140 Calculated from Danish Energy Agency. (1998a). *Energy statistics 1998*.

141 Calculated from STEM. (1999b). *Energy in Sweden. Facts and figures 1999*.

Different industry background is another limitation. Sweden had a large electricity appliance manufacturer, ASEA (present ABB). It has participated in developing nuclear reactors since 1950s and become a part of Swedish nuclear industry and thus a part of "the establishment." It could easily be deduced that it has been influential on Swedish society in directing toward large-scale centralised energy system. Although it does not sell any nuclear reactor in Sweden anymore it is still a part of "the establishment." It is natural that "the establishment" based on centralised large-scale energy system holds negative attitude toward wind power as a small-scale decentralised system. Current trend that ABB moves toward decentralised energy system might change this feature. It is certain, however, that it will take long time for the shift of whole system as it took long time to establish the current system. It can be concluded that the existence of nuclear industry is one of the reasons that keep wind turbine industry from developing in Sweden.

Finally but most important fact is wind power is not the only option for Sweden. Aside from nuclear power that will be phased out in the future, Sweden is rich in other renewable energy sources, i.e. hydropower and biomass. Biomass has more possibilities to contribute to national economy in that Sweden has already knowledge of technology that can be exported to other countries. Possibilities of wind turbine export are not as high as those of biomass due to young wind turbine industry in Sweden. Therefore wind power development does not necessarily bring about benefit to Sweden. This is the main difference of implication of wind power development in Sweden and Denmark.

8. Conclusions and Recommendations

This thesis has tried to answer why wind power has been successful in Denmark and not in Sweden. Future possibility of wind power development in Sweden is also investigated.

First it is clarified that it is governmental initiative that has enabled Denmark to develop wind power to the present situation. Danish government has been active in promoting sustainable energy source including wind power since 1980s. Although in every micro level positive driving factors can be found in Denmark not much would have been possible without macro government initiative. It has been the national interest to promote wind power in Denmark. Wind turbine industry has contributed to national economy by exporting the products. Strong government initiative to commit consistent policy is necessary condition for wind power development. With resolute determination to increase wind power the Government implicates all of the concerned parties into its policy.

Private enthusiasm and entrepreneurship have lead early development of wind power utilisation and has been the diving force for Danish wind energy system toward wind power expansion. Private ownership to such extent has been possible due to favourable loan provided by Danish financial sector. Such an offer was also inspired by governmental reliable policy. Although future development is toward offshore wind power it will still play important part in wind power.

Another important aspect is that power industry is also involved through agreement with the Government to install certain capacity of wind power by certain time. Such agreements have been reached four times since 1985 and so far 200 MW of land-based wind turbines are installed. The latest agreement is to develop 750 MW offshore wind power during 2001 and 2008.

It is also underlined that it is important to involve power industry from early stage of wind power deployment planning. It is quite reasonable to involve power industry in municipal spatial planning as it enables organised wind power development in terms of transmission capacity.

These electricity supply system support (toward private individual and power industry) also created reliable domestic wind turbine market, which in turn resulted domestic wind power industry development. Because of constant demand for wind turbines supported by consistent governmental wind power policy and with industrial background of agricultural machinery manufacturing the domestic wind turbine market is created in Denmark. Domestic demand has better advantage compared to foreign one in improving the quality of products. The former can reflect the customers' satisfaction/dissatisfaction to product improvement much faster than the latter. And many of wind turbine industry are located at neighbour of wind power sites. This geographical proximity contributed many of improvements in Danish wind turbines. Today Danish wind turbine is said to be one of the most competitive products in the world wind turbine market.

In this way Denmark has succeeded in increasing wind energy capacity since 1980s. It has achieved wind energy capacity of 1750 MW in 1999 and production of 2.8 TWh in 1998. Even Denmark, however, is not free from barriers for farther wind power expansion. It is limitation of available land. To overcome this inevitable obstacle Denmark has decided to stake offshore possibility. And it is steadily approaching to the goal by involving power industry.

In Sweden a number of barriers are identified, among others political uncertainty is the most significant from several interviews and questionnaires. Variability is the characteristics of Swedish energy policy since 1980s.

Political uncertainty is closely related to lack of strong governmental commitment, which is main reason for absence of harmonization between different governmental levels. It creates administrative barriers. Because of administrative barriers response in regional and local government is slow in issuing building permission procedures. It is also caused by complex building code, which is very much linked to environmental regulations. Too much stress on environmental protection in legislations hinders construction of wind turbines in windy places. Delayed building permission is often pointed out as barriers by several parties including wind turbine industry, power industry and wind developers.

Another consequence of political uncertainty is unwillingness in financial sector to support wind project. It creates economic barrier. As policy reliability is not so high among financial sector it fails to create favourable investment climate for wind project. To make the matter worse there are negative conditions for wind power in the Swedish electricity supply system. Cheap price of electricity has been without doubt one of the barriers for wind power development in Sweden.

Contrary to assumption that strict environmental regulations lead low public acceptance of wind power, it is not identified as barriers in Sweden. Public hold much positive attitudes toward wind power. It can be verified from the facts that over 10,000 families have invested their money on wind power project. Consumer demand on green electricity is also a sign of possibility for further wind power development.

If Sweden were to develop wind power as Denmark, it could apply some of its experience. The Government should put priority in achieving consistent governmental policy toward wind power development. As a starting point it is important to establish wind power as a national interest. For example it can be achieved by disseminating the fact that wind power can contribute protection of natural environment. Amendments in notorious building codes are one alternative. Not only visual and noise disturbance but also carbon free characteristics should be taken into account. It is important to compare all aspects of wind power with those of other energy supply system. It will be easier to accept wind power than other conventional energy sources when every aspects were considered.

At national level Government has recently started to commit itself to wind power expansion. At regional or local level where building permission procedure takes place, the authorities are often not ready to involve themselves in active development. Delayed building permission issue is partly due to the fact that municipalities do not have enough financial and human resources. As a first step national government can allocate specific resources for wind power development. Wind experts delegation to local authorities is one way of information dissemination. Basic information and education about wind power would facilitate persons responsible for wind power decisions in communes and county administrative board to make reasonable decisions. And establishment of an information centre for wind power in Aeronautical Research Institute is one option.

Next step is to establish clear official target for wind power installation. In addition to appropriate resource allocation on wind power development it will relieve the administrative barrier, i.e. lack of coordination between different governmental levels. Once national target is created it would be easier to break it down into regional targets or even local targets, which will promote wind power installation in practice.

Clear national target can convince investors to recover their investment thus partly overcome economic barriers. This target should be consistent with initiative in deregulated electricity market. Under liberated market it is true that it is the market that decides the price of the electricity. There is still important role of government, i.e. to carry out consistent policy. Consistent governmental policy includes clear vision on several policy instrument including subsidies on wind turbine installation and the green certificate system. Swedish government can learn a lot from Danish experience in that clear policy create reliable market for wind turbines and thus contribute to national economy.

Consistent national policy does not necessarily mean to support with heavy subsidies. Governmental intervention is rather limited compared to Denmark. What is necessary is to set non-discriminatory market conditions that wind power can compete other energy sources on the same ground. Particularly it is necessary for wind power to be incorporated into current energy system. Introducing CO_2 tax on fuel used in electricity production to internalise social costs is one option.

Possibility of the power industry involvement in wind power policy is rather limited in Sweden compared to Denmark. Clear political signal can, however, influence its future investment strategy toward wind power in positive direction.

One crucial issue is that Sweden cannot gain the same benefit from wind power as Denmark enjoys. Sweden has other choice than wind power to achieve climate change target. Under deregulated electricity market it is not necessarily cost-effective to promote wind power. Neither biomass is uncertain in cost-effectiveness.

Although rather behind Sweden still has potential to develop wind power. It depends on Governmental commitment whether it can be further promoted or not. The Government should find cost-effective way to meet the targets in international agreements including Kyoto protocol.

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Abbreviations

EFP Danish Energy Research Programme

IEA International Energy Agency

KML (1988: 950) Cultural Monument

MKB Environmental consequence description

ML (1969: 387) Environment Protection Act

NRL (1987: 12) Natural Resources Act

NVL (1964: 822) Nature Conservation Act

PBL (1987: 10) Planning and Building Act

STEM Swedish National Energy Administration

UVE Danish Renewable Energy Development Programme

WTP Willingness to pay

Appendix

Questions to Danish (Swedish) authority

1. What are drivers for the development of wind power in your country?

- Government initiative, industry initiative, consumer's attitude or something else

2. What do you think as barriers?

3. What have you done for supply-side policy for wind power?

- Regulations, subsidies, etc.

4. How do you evaluate your initiative to promote wind power?

5. What is your demand-side (consumer) policy to promote wind power?

6. What do you think about wind power development in Sweden (Denmark)?

7. If you have anything that you want to comment on wind power development please write down.

Questions to Danish (Swedish) power industry, wind turbine industry and wind developers

1. What do you think as drivers and barriers to wind power development in your country?

2. How barriers can be overcome?

3. What do you think can be done to promote wind power further?

4. From industry point of view do you think wind power as a promising option for future?

5. How do the national government commitment (to develop wind power) affect your decision making?

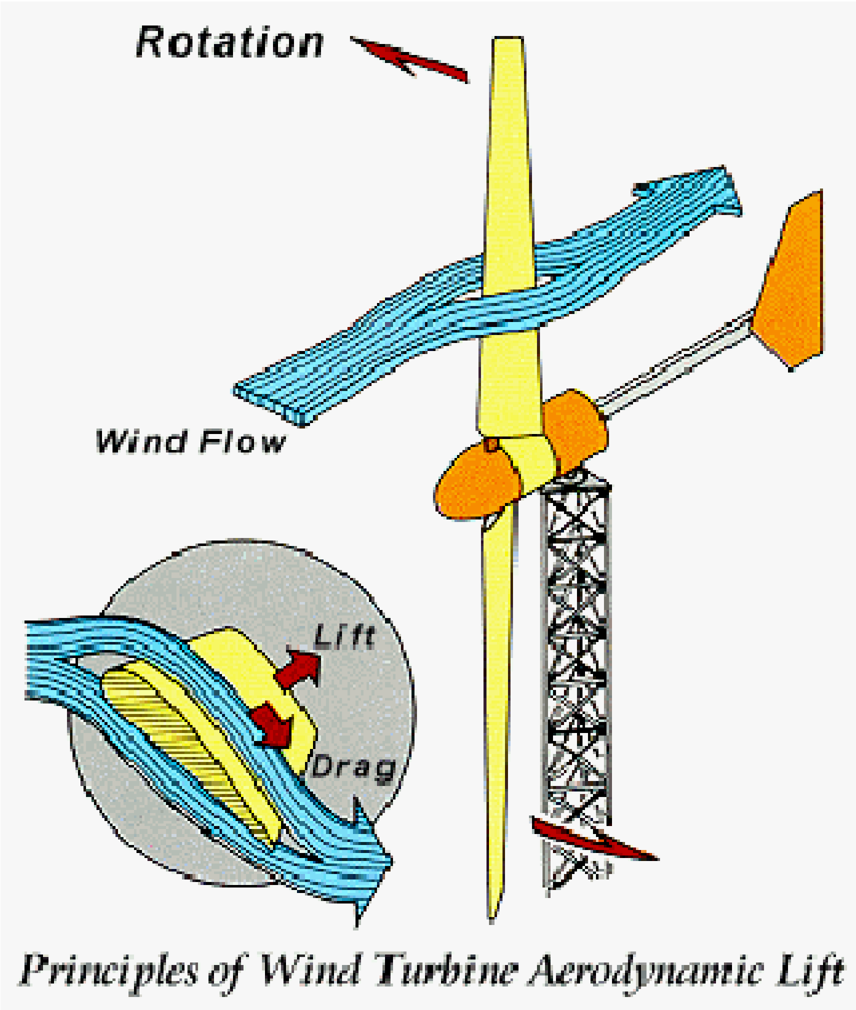
6. What do you think about wind power development in Sweden (Danish)?

7. If you have anything that you want to comment on wind power development please write down.

Table A-1 Results from questionnaires

	Sweden	Denmark
Drivers		
- Government commitment	2 (a power company and a wind developer)	3 (power association, a turbine company and wind turbine manufacturers association)
- Subsidies	2 (two power companies)	2 (power association and a turbine company)
- Climate change issues	2 (a turbine company and a wind developer)	
- Consumer demand	1 (a power company)	
- Industry background	1 (a turbine company)	
Barriers		
- Deregulation of electricity market	1 (a power company)	2 (power association and a wind turbine company)
- High price of wind-generated electricity	2 (two power companies)	1 (power association)
- Environmental regulations (building permission issue)	4 (a power company, two turbine companies and a wind developer)	
- Public acceptance		1 (power association)

Figure A-1 Basic aerodynamic principles



Source: American Wind Energy Association. (1998).

Recent Development in Environmental Economics Part 1

The role of green accounting in sustainable development

- Survey of integrated environmental and economic accounting systems -

Zoltan Denes
Hitotsubashi University,
Graduate School of Economics

Hitotsubashi University, Graduate School of Economics

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－Survey of integrated environmental and economic accounting systems－

Zoltan Denes

Contents

Introduction

The environment supports life on earth, and plays an important role in economic activities. It provides resources to production and consumption, assimilates waste, provides space for living and recreation, and contributes to human welfare through amenity. Despite the general agreement on these facts, environmental depletion and degradation, including damage to human health, has shadowed the path of economic activities even before the industrial revolution. It left England virtually without forests, bad sanitary conditions facilitated the spread of plague and other diseases. In the mid 19^{th} century citizens of large industrial cities were dying of smog, and living conditions were horrifying. Despite the obvious relationship between production, consumption and these environmental problems, emerging economic theories of the time did not incorporate the environment in their model of the world. The economic system is represented as a self-sustaining circular system of production factors and products, consumption and production, with neither external inputs, nor anything leaving the system – a perpetuum mobile. Branches supporting economic theories, such as national accounting, not surprisingly, followed suit and incorporated the environment only as much as it was necessary to help these economic theories. The current System of National Accounts (SNA) is constructed along the same line, and includes only those natural resources that qualify as economic assets. It is an economic accounting system after all, for regular collection and presentation of economic data, and for providing economic indicators.

In recent decades, however, it has become clear that human activities can leave a lasting effect on the environment. Increasing scarcities of natural resources threaten the sustainability of production and consumption, as well as degradation of environmental quality due to excessive pollution is jeopardizing nature's life supporting functions, biodiversity and human health. In addition to immediate threats, mounting evidence points to the risk that many of these environmental burdens will be shouldered by future generations, unless we integrate environmental concerns and economic goals for a common purpose. 'Sustainable development' gives a conceptual background to the integrated environmental and economic theories, which incorporate the well being of present and future generations equally. These theories are in their early stage of development, but as with economic theories, a supporting accounting system with multiple functions is desirable.

The purpose of this essay is to observe and judge how far we have managed to integrate environmental and economic accounts to help integrated policy making for sustainable development. The survey will review emerging frameworks of the present; focusing on the key aspects of these concepts, fundamental differences, trial estimates and possible policy uses. In addition, both the historical and conceptual background to integrated accounting will be presented. The final goal is to identify those points that need to be attended in the future.

Chapter 1.

Background to ‘green accounting’

Section 1.1

From the SNA to satellite accounts

In the late 17th century in England, William Petty[1] estimated national income to find out how best to finance wars. These are thought to be the first calculations of national income. Economic statistics of the present serve multiple purposes, and the inventory of annual income is only one, albeit an important one of those. National statistics are also the database for time-series analysis in any country, they help international comparison、and also act as a database for growth models and other econometric models applied in economic policy-making. The importance of empirical and statistical work is twofold: (a) conclusions on how the economy works can be drawn and theories established, and (b) proposed economic theories can be verified or disproved by checking their claims against collected and recorded data. The faithful record of data is a prerequisite to either of the purposes.

The most prominent economists who began to standardize the rules of national accounting were Simon Kuznets in the United States and Richard Stone in England in the 1930’s and 40’s. The exchange of views in *Economica* by Kuznets (1948/a, 1948/b) and Hicks (1940, 1948) manifests the issues that were being debated during the evolution of the national income accounts and the indicators derived from them. One of the central elements of the debate focused on the relationship between welfare and an indicator of economic activity. Can such an indicator reflect welfare? If so, how should it be composed and how should the items be valued? Kuznets advocated the exclusion of those government expenditures that cannot be classified as final products, which yield immediate economic welfare to the ultimate consumers. Government expenditure items to be included, however, had to be valued at cost, because they did not have a market price, and private sector equivalents were not always available. The valuation of the government sector at cost can be found in the System of National Accounts; the exclusion some government expenditure was dropped. Despite the objection to including defensive or intermediate government expenditure on the welfare ground, they are incorporated to help Keynesian economic analysis and policy-making, in which fiscal policy has a central role.

GNP/GDP quickly gained ground as a powerful measure of a country’s economic activity, regardless its welfare implications. This does not mean, however, that there were no suggestions for other indicators in the following decades, which reflect welfare better than GDP or integrate

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[1] William Petty, Political Arithmetic, 1690

economic development with other factors of welfare. None of the serious suggestions, however, suggested the replacement of GDP or SNA, because as Nordhaus and Tobin (1972 p.1) put it: "… Gross and net national product statistics are the economists' chief tool for short-run analysis, forecasting, and policy and are also indispensable for many other purposes". These supplementary indicators and accounts got 'official' approval by the introduction of satellite accounts[2] in the 1993 SNA. The aim of such satellite accounts is to:"…try to design an accounting framework to cover a wide variety of cases, all of them belonging to a family of functionally oriented satellite accounts. Such accounts are relevant for many fields, such as culture, education, health, social protection, tourism, environmental protection, research and development (R&D), development aid, transportation, data processing, housing and communications."[3] The environment got special attention to "respond to the growing concerns of incorporating environmental criteria in economic analysis" [4]. Details on suggested implementation were also published in the same year (UN, 1993/a), and an operating manual in 2000 (UN, 2000). The SEEA framework and other suggestions will be elaborated on in Chapter 3.

As for the environmental accounts[5], there are no internationally accepted and advocated standard rules, similar to the SNA format. One reason is that the description of both the state of the environment, and particularly its dynamics is far more complex than those of the economy[6]. Therefore, there is no fixed format of data collection. Despite this fact, there are innumerous statistics collected internationally and nationally. International organizations generally concentrate on either global environmental problems or specific areas, geographically or thematically. At the national level there are zillions of environmental related data in developed countries. For example, The Ministry of Environment of Japan has published annual reports on the state of the environment since 1969, called the 'Environmental White Paper'. Statistics are organized by 'problem areas', such as air pollution, water pollution, noise pollution waste, wildlife, and so on. While probably this representation informs us about the state of the environment in the most comprehensible way, we ended up with a system that has a completely different structure from the SNA, where transactions are recorded under economic agents. This mismatch is rather unfortunate when our goal is the integration of the two systems.

Since the incorporation of the satellite accounts concept in the 1993 SNA, numerous such systems regarding the environment have been suggested. O'Connor et al. (2001, p. 5) divide frameworks concerning "greened national accounting" into the following three main categories:

1. National Accounts directly expanded with information on the environment
2. Separate satellite accounts

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[2] System of National Accounts 1993, Chapter XXI, United Nations, 1993
[3] Same as footnote 2
[4] Same as footnote 2
[5] Data on the environment itself, and also on pollution, waste, etc.
[6] "There is no widely accepted model of the transformation processes taking place within the natural environment and of the dynamics of the economic influences acting on it." (SEEA, UN, 1993 p.6)

3. Adjusted Aggregates

The first one is strictly built on the SNA, therefore the structure and accounting rules are kept the same. In contrast, the second and the third one can be tightly or loosely connected to the SNA and O'Connor calls these satellite accounts. OECD (1995 and 1998) introduced different terminology when grouping concepts of environmental accounting:

1. Natural resource accounts
2. Satellite accounts
3. Adjustment of the System of National Accounts

Natural resource accounts record quantitative and qualitative information on the stocks and flows of natural resources in physical units. The framework of these accounts do not relate to the SNA. *Satellite accounts* establish the link between the physical information drawn from the natural resources accounts, environmental statistics and the economic data recorded in the national accounts or imputed damage costs, without modifying the system itself. It is also possible to calculate adjusted aggregates indicators. *Adjustment of the System of National Accounts* approaches try to account for environmental issues that are currently missing from the national accounts, such as degradation and depletion of resources, by broadening the framework of the SNA. These concepts naturally result in adjusted aggregate indicators.

In reality, however, no serious suggestion intends to reform the SNA, and no country plans to replace the current system with an adjusted one. Therefore, all suggested systems, linked to the SNA, are satellite accounts, regardless their aim to adjust aggregate indicators or not. Environmental accounts, which are not satellite accounts, are those that are not indented to be directly related to the SNA. The trend today suggests that, while some of these accounts are important and have to be maintained as they are, the linkage to the SNA is indispensable to understand the relationship between the economy and the environment.

Regardless the details of each concept, it is crucial to have a clear picture of what an *ideal* integrated environmental and economic accounting system would look like. This way, it will be easier to identify points where more research is necessary, or where we might have to make compromises given the difficulties of certain issues.

- It has to be consistent with the current national accounting system, thus it necessarily has to follow existing accounting rules. Changing the core SNA does not incur as an option, which implies that environmental statistics should be adjusted accordingly.
- It must be comprehensive enough to adequately cover all, important national environmental issues.
- It should cover some aspects of global issues, perhaps as much as the SNA covers the rest of the world by export and import accounts.
- It has to be flexible to incorporate further environmental issues if necessary.
- It must be constructed in a way so as to help integrated environmental and economic

modelling and decision-making.

- ✧ It should provide a number of comprehensible and useful aggregate indicators to convey information on the environment and the economy to the public and policy-makers.
- ✧ It has to be scientifically well founded, containing as few assumptions as possible.
- ✧ It has to be based on observable and collectable data, including as little estimation as possible.
- ✧ It has to be implementable on a regular basis.
- ✧ It should be internationally uniform to provide comparable results.
- ✧ Intragenerational and intergenerational accounting principles should be developed and incorporated.

Section 1.2

The concept of sustainable development and its linkage to integrated accounting

The first international resolution, which considered the pressing need for clearly defined principles to guide nations to a path where preservation and improvement of the human environment are taken into account was accepted in Stockholm in 1972 by the United Nations Conference (UN, 1972). In addition to the necessity to improve the environment of people living ‘under minimum level’ at present, the importance of considering the ‘benefits’ of future generations, which result from using the environment were emphasized.

‘Our Common Future’ (The Bruntland Report), prepared in 1987, and published by the World Commission on the Environment and Development (1989), clearly spells out the dangers, which result from practices followed by industrialized and developing nations alike, to base growth on ecologically unsustainable economic activities. The urging need to weigh economical and ecological considerations equally was stressed. In the report the most widely used definition of sustainable development was also formulated: “*development which meets the needs of the present without compromising the ability of future generations to meet their own needs.*”[7]

In 1992, almost 180 countries met in Rio de Janeiro at the Earth Summit to discuss different dimensions of sustainable development and necessary steps to achieve that goal. A plan of action ‘Agenda 21’ (UN 1993/b) was agreed on, and recommendations made that all countries produce strategies to achieve sustainable development.

To be able to put the concept into practice more detailed goals and definition were necessary. Research during the early 90’s elaborated on, and fine-tuned the concept, and different ‘versions’ of sustainability were identified.

One commonly quoted categorization differentiates ‘weak sustainability’ and ‘strong sustainability’ (Pearce, 1993). These concepts are rooted in the assumption that for sustainable

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[7] World Commission on Environment and Development: Our Common Future (1989) pg.363

income we have to maintain capital at a certain level, so that future generations will have at least as much capital base to build their economy on, and to derive income from it, as people living now. Under weak sustainability conditions natural capital stock is no different from any other form of capital, man-made or human, full substitutability is assumed between them. Strong sustainability, on the other hand, assumes that the degree of substitutability between ecological and man-made capital is limited, and the sustainability of each has to be monitored. The broadest views consider four types of capital: man-made capital, natural capital, human capital and social capital (Serageldin and Steer, 1994). For practical purposes most approaches stop at extending the asset accounts with types of natural assets that do not enter the equations of economic policy planning of the present, and are not included in the SNA.

Despite the several categories and definitions of sustainable development, there is a general agreement that sustainability has two objectives: on the one hand, to achieve improvements in the life[8] of the billions of people who live in poverty now[9]; on the other hand, the achieved development has to be sustained: realized progress today must not be at the expense of the generations to come. Several questions are still open, however. How far ahead do we have to think, to what extent the living standards of the poor have to be improved, etc. Nevertheless, following the recommendations of Agenda 21, many countries included sustainability in their government programs and/or legal regulations. Major international organizations set up separate institutes or departments, such as the United Nations Division for Sustainable Development, to develop the concept of sustainability, and to come up with practical suggestions about strategies, policy planning and measurement. Governments of some countries followed suit and established institutes to work on sustainable development. In recent years, research, both at national and international level, focused on the practical questions of implementing sustainable development.

Firstly, a lot of work has been done on developing some kind of measurement or indicator system that would tell us whether our environmental socio-economic system is on a sustainable path. Secondly, intensive research is being carried out to formulate integrated environmental, economic and social policies aiming at sustainable development. These two areas are strongly related and research overlaps are common. Among several means aiding the construction of integrated policies, the potential *integration of environmental and economic accounting systems* has drawn a lot of attention from the beginning. Agenda 21 Chapter 8 paragraph D (U.N. 1993/b) directly calls for setting up an integrated environmental and economic accounting system, and Chapter 40 states the importance of information and data availability for sound decision-making. The document also spells out the necessity to develop indicators of sustainable development, since neither current macroeconomic indicators, nor unconnected pollution or resource data charts provide adequate signal of sustainability. Establishing the link

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[8] Synonyms used in related literature include: well-being, welfare, living standard, and livelihood.
[9] In a broader sense, increase the welfare of all citizens of the world, but poor should have priority.

between these currently unconnected statistics is exactly the role of integrated accounting.

An integrated environmental and economic accounting system would both suit the purposes of policy development, decision-making, detailed economic analysis, would serve as a database for macro-economic modelling, and would provide us with aggregate indicators to judge our progress towards sustainable development. Therefore, suggested sustainability indicators have been evolving hand in hand with integrated accounting systems.

Section 1.3.

Sustainability indicators and frameworks, an overview of opposing points

In the last decade the development of sustainability indicators has been attempted at all levels, from research groups to the United Nations, and indeed, a large number of diverse suggestions have been put forward. The importance of reviewing these ideas here is that even if a generally accepted integrated environmental and economic accounted system is introduced; it might not provide us with enough indicators on sustainability and/or development. Four sets of opposing points will be identified; examples of each one will be given. For reference the full names are listed below[10].

α) Stand-alone[11] indicators or indicator frameworks (HDI, GPI, PSR & DSR frameworks)

as opposed to

β) Indicators derived from integrated accounting systems (SEEA, NAMEA)

Accounting frameworks are complex and have to follow certain accounting rules. Why environmental indicators are not enough on their own? Keuning's answer (2000 p.77): "If one aimed at maximizing an environmental objective, operationalized by an indicator that is not derived from an accounting framework, it would be impossible to assess the repercussions of another value of this indicator on another macro-economic objective." At present, however, the integrated accounting frameworks are not in the state of development to be introduced on a full scale. Integrated accounting systems will be discussed in Chapter 3; here I would like to introduce some stand-alone indicators or frameworks.

The stand-alone indicators have two advantages over accounting systems. Firstly, it is easier to develop them because they do not have to follow accounting rules. Secondly, they are

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[10] HDI: Human Development Index, PSR: Pressure-State-Response, GPI: Genuine Progress Indicator, DSR: Driving force-State-Response, SEEA: System of integrated Environmental and Economic Accounts, NAMEA: National Accounting Matrix including Environmental Accounts, ISEW: Index of Sustainable Economic Welfare, NNW: New National Welfare, MEW: Measure of Economic Welfare, geGDP: greened economy GDP, EDP: Eco-Domestic Product, EANP: Environmentally Adjusted Domestic Product, SMS: Safe Minimum Standard

[11] 'Stand-alone' is used for concepts that are not related to accounting frameworks.

more flexible, new factors are easier to incorporate, especially if they form a framework such as the Pressure State Response (PSR) and the Driving-force State Response (DSR) frameworks. On the other hand, they have the disadvantage that the indicators are often not interlinked.

The Human Development Index (HDI) is an index advocated by the United Nations Development Programme, which combines information on aspects of education, life expectancy and GDP (UNDP, 2001). Natural environment is not taken into account, so this index tells us only about socio-economic development.

The Genuine Progress Indicator (GPI) includes factors in ten categories, such as aspects of the environment, crime, leisure, households and volunteer work, income distribution, reliance on foreign assets, etc. all converted into monetary units, weighted and aggregated (Redefining Progress, 2001).

The DSR framework (U.N., 1999) covers several dimensions of sustainable development. In 1995, the United Nations Commission for Sustainable Development (CSD) adopted a set of 134 indicators in a matrix format in its work programme. The rows represent the categories in four sets: social, economic, environmental, institutional; and the columns are the driving-force, state, response indicators. The *driving force* indicators describe the human activities that affect sustainable development, *state indicators* describe the current state of sustainable development, and *response indicators* point to policy implications. The environment has the largest share among the four dimensions of sustainable development with 55 indicators of the 134. The DSR framework is detailed, covers a large number of important areas and tries to establish the link with sustainable development by identifying targets where possible. The DSR framework is intended for use at national level, many details would have to be clarified and targets identified by each country. The PSR framework of the OECD is a very similar system, focusing only on the environment and can be considered as a predecessor of the DSR framework. Now, the EU is looking into possibilities for further improvement with the Driving Force-Pressure-State-Impact-Response (DPSIR) framework.

α) Approaches involving a high degree of aggregation (Genuine savings, HDI, GPI, EDP)

as opposed to

β) Approaches with little aggregation (PSR, DSR)

The notion of 'indicator' and 'index' are often used when describing the performance or state of the economy, the environment and social issues. A definition is provided by the OECD (1998, p.107) specifically for environmental indictors: " A parameter or value derived from parameters, which points to, provides information about, describes the state of a phenomenon/environment/area, with significance extending beyond that directly associated with a parameter value." Here, parameter is: "a property that is measured or observed." An index is an aggregated figure, which we get by a certain (weighted) combination of indicators. Indicators usually have some kind of unit of measure, whereas indices are generally numbers without a unit of measure, and often combine information from very different fields.

Aggregation can be a useful process, since it provides information in a concise, easily comprehensible format. On the other hand, this result in the loss of details and therefore might limit its usefulness, especially for policy-making. A systems such as the DSR framework can be quite useful for experts' evaluation, but would certainly fail the task to inform the public with well over a hundred indicators and indices. We need different levels of aggregation for experts and for the general public or policy-makers.

There is a danger in aggregation, however. Not only details disappear through the aggregation process, but also things that are not substitutes are treated as if they were. For example, the imputed monetary value of environmental damage is subtracted from NDP to arrive at EDP. In situation when the increase in GDP exactly counter balances the negative effect of computed environmental loss, EDP does not change, whereas the real situation before and after is clearly different.

Instead of this, another option is to introduce a certain number of social and environmental indicators to inform the general public. It is this 'certain' number that is difficult to decide on. There are, in fact, attempts in this direction, trying to find the 'golden level' of aggregation and at the same time keeping separate fields apart. One of these is the NAMEA approach, which will be introduced in Chapter 3. Another one is prepared by the British Government (2001), which developed 15 sustainability 'headline indicators'[12], 7 of which are environmental indicators[13]

α) Flow based indicators (EDP, EANP, NNW, MEW, NAMEA)

as opposed to

β) Stock based indicators (Genuine savings, SMS)

Flow and stock based indicators can be either in physical or monetary units[14].

Flow based indicators, which intend to adjust GDP naturally involve monetary valuation of *degradation and depletion* of the environment. The idea behind these is analogous to NNP, which is the highest achievable income in a period, without reducing future consumption possibilities by living up productive capital stocks. Thus, the adjusted indicator can point to environmentally sustainable (or unsustainable) consumption.

There are, however, several specific problem areas (Hanley, 2000), both technical and theoretical. *Depletion* paths for resources are not always optimal[15], thus prices are distorted. Even if they followed an optimal depletion path, it would only mean efficiency and not equity, which is

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[12] Altogether there are 150 indicators and the aggregation process leads to 15.

[13] Environmental indicators are climate change, air quality, road traffic, river water quality, wildlife, land use and waste.

[14] The economic indicators are expressed in monetary measures and environmental indicators are expressed in physical units, or both in monetary units.

[15] Meaning inter-temporally efficient depletion of resources. Hanley, Shogren, White: Environmental Economics (1997) Chapter 9.

one key element of sustainable development. In addition, the valuation of *degradation* (pollution damages) itself is a rather complicated issue as will be point out later.

There are concepts that do not apply monetary valuation; they only record the annual flow of pollutants or resources. These, by themselves, neither give information about the damage caused, nor on the sustainability of resources. We can use time series to see if the pollution decreased or not, but a decline still may not mean sustainability. This is especially true for accumulating pollutants. There are attempts to tie the flows to some standards and these will be discussed in the NAMEA section. Flow of resources too, only have a meaning if they are connected to the sustainable or unsustainable use of the resource.

Stock based approaches are based on the notion that welfare is derived from capital stock[16] which have to be maintained at least at a certain level to 'produce' the same level of consumption that we enjoy now. First we have to identify these stocks, then decide on the level to be maintained. Several approaches can be mentioned.

The Hartwick rule (or Solow-Hartwick approach) says that the stock of capital can be kept constant by reinvesting the rents from non-renewable natural resources into man-made capital. The sustainability condition would be to check whether this requirement is met or not: the level of current capital stocks have to be maintained and it does not matter if the capital is man-made or natural as long as the total remains the same. The basic argument, however, breaks down if not the optimal path of depletion is pursued, thus the rent, and along with it the investment are not what they should be. For example, too low natural resource prices would indicate insufficient investment. Hanley (2000) concludes that the Hartwick rule tells us nothing about sustainability, and would only be useful if we were already on a sustainable pass, but that in turn makes the rule unnecessary. Secondly, there is no evidence that elasticity of substitution between man-made and natural capital is one or higher as suggested by the Hartwick rule. Christensen (1989) argues that man-made capital and natural resources are complements, and treating them as substitutes is fundamentally wrong. Erlich (1989) points to the fact that natural resources are not only inputs into economic activities, but important assets, for which there are no, or only very imperfect substitutes. Finally, sustainability is about welfare and not about consumption. Therefore, even if resources were substitutable for each other as inputs, the fact that people derive welfare directly from 'natural resources' is ignored.

Another approach, which similarly does not distinguish between natural and man-made resources, is the Pearce-Atkinson Measure (PAM). This indicator is not fundamentally different from the Hartwick rule, it is more like testing if countries meet it or not. The depreciation of produced capital and monetary values of the depletion of natural assets are deducted from savings to arrive at the PAM. The 'genuine savings' indicator is basically the same but expenditure on

[16] Also referred to as assets or resources.

education is added[17]. Genuine savings could be a measure of weak sustainability. Not meeting weak sustainability implies that strong sustainability would not be met either (by definition).

There are two approaches, the 'constant natural capital'[18] and the Safe Minimum Standard, which distinguish between different forms of capital. They keep a record of environmental stocks in physical units, which is closer to the idea of ecological sustainability. The difficulty is to decide how specific we have to be. We can decide only to measure the area of a forest and ignore the species of trees, but forestry experts would surely object to it. So how far do we have to go down with the specification? There are no clear answers, but there are physical and cost limitations to the collection and process of the enormous amount of data, therefore some categorization of the natural assets is unavoidable. It is not clarified in these approaches how a certain level of non-renewable resources could be maintained unless we seize their depletion when reaching that level. Daly (1993) suggests that the rents from non-renewable resources should be invested in renewable ones, therefore allow for some substitutability between two.

Finally, the constant capital stock approach might put unbearable burden on the economy. The accounting period is normally a year, while recovery of renewable resources usually takes longer. But this would not be allowed under this approach, unless we define much longer accounting periods.

The constant capital stock approach and the SMS approach are very similar. There are two main differences. One is that under the constant capital approach natural stocks would have to be kept at the current level, while the SMS requires the level to be maintained above a certain 'safe minimum standard' to guarantee the continuation of the natural resilience of the resource, i.e. its ability return to the normal state after a shock[19]. The other one is that this minimum level is to be maintained only if the social opportunity costs are not 'intolerably large'. What constitutes 'intolerably large' has to be based on social consensus. For larger projects a referendum might be necessary or they may be decided at elections. Smaller issues would have to be decided by relevant government agencies. The SMS, the level itself, is difficult to decide, mainly because of the ecological interlinkages between certain categories, and thus their sustainable level. For example, the sustainability of whales and that of the fish stock are linked and setting unrelated SMS might not bring the desired results, but these level are internationally disputed currently. Moreover, the critical minimum level of stock has to be scientifically 'fail proof'. As Hanley (2000) pointed out, if the SMS in 'first period' is set and maintained (i.e. sustainability met), but it turns out in the 'second period' that the level was set too low, we have to *ex post* declare the first period unsustainable and we may endanger the long term ecological sustainability of the species.

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[17] Education expenditure is considered to be investment in human capital (Hamilton, 1994), but El Serafy (1997) argues that not all education leads to higher productivity, therefore its addition is not founded. Degradation of environmental assets is also deducted in some versions (Bartelmus, 1999).

[18] Also called 'non-declining natural capital stock' (i.e. increase is allowed)

[19] This obviously only refers to renewable resources.

α) Concepts involving monetary valuation (SEEA, GPI, MEW, NNW)

as opposed to

β) Concepts avoiding monetary valuation (NAMEA, PSR, DSR, SMS

The monetary valuation of different aspects of the environment is one of the most extensively discussed topics of environmental economics. The area that divides economists into almost two separate groups is that of environmental degradation, i.e. decrease in quality of the environment, including polluted air, water and soil, loss of biodiversity, deteriorated human health, even foul odour and visual disamenities. An interesting observation is, that the point of disagreement is not the ‘invaluable’ human life. Despite moral reservations, there are several methods for valuating that, such as from insurance policies, compensation payments, lost production capacity and others. The extinction (if it occurred) of the Japanese Giant Salamander (Andrias japonicus)[20] is a lot more complicated issue, partly because it has neither insurance, nor economic productive capacity; more seriously, the extinction of the species would probably have no effect on the economy directly. Placing monetary values on the ecosystem, or part of it, is fully rejected by many people, especially outside economic circles (Beder, 1994). Those economists who advocate monetary valuation acknowledge that there are some controversies during the valuation process, but they point to ‘not fully developed’ methodologies.

The key points put forward in favour of monetary valuation are as follows. Firstly, monetary valuation is the only way to arrive at a common unit of measure and thus the only way how algebraic operations (addition, subtraction, comparison, etc.) can be executed between new and traditional accounting aggregates, and accounting identities can be established. As Bartelmus (1999, p.1) stated about indicators in *different* units: …”their *policy relevance is limited* unless they can be linked to sustainability standards or other targets and thresholds, which are difficult to agree upon” (emphasis added). Secondly, NDP already includes the concept of sustainability of consumption. An amendment of these will serve as sustainability indicators in a wider sense. Thirdly, a national level cost-benefit analysis cannot be implemented without monetary valuation.

Physical approaches advocates claim that sustainability has several dimensions. While searching for the linkages between these dimensions is crucial, aggregating the improvement in one with deterioration of another is conceptually wrong, a common denominator, such as money is not necessary in the first place. As pointed out by van de Ven et al. (1999, p. 8) “The main problem in this regard is that such a single indicator has *no relation whatsoever with policy options*” (emphasis added). The physical approach advocates see the common measure (the money) as a misleading ‘device’, whereas the monetary approach advocates see it a valuable property, and both state that the other approach is not useful in policy planning. Secondly, imputing artificial cost values to environmental problems and adjusting GDP is thought to be a

[20] An endangered species in Japan, designated as a ‘Special Natural Monument’, and is legally protected since 1952. Source: www.endangeredcreatures.com

strange idea. Keuning and Steenge (1999 p. 5) drew a parallel: "nobody seriously proposes to value the 'cost' of unemployment and to 'subtract' this from GDP."[21] It is also pointed out, that regardless the calculation method of the environmental 'costs', it is fundamentally wrong to deduct these costs from GDP, because the units are not the same as claimed, thus such an algebraic operation is not justified (van, de Ven, 1999). GDP is in 'real money' that actually entered transactions (real dollars), whereas imputed environmental costs are in a 'hypothetical money unit' (imputed dollars).

Although the most controversial point is the monetary valuation of the degradation of environmental assets, the depletion of renewable resources poses considerable difficulties, already. Forest resources are important sources of income in some countries; therefore depletion of these resources jeopardizes the country's future income flow, thus sustainability. Repetto et al. (1989) studied timber resources in Indonesia between 1970 and 1984, and concluded that Indonesia was living up its natural capital and the economic performance of the country would require a serious downward adjustment[22]. Market values, however, ignore many important ecological and recreational aspects of forests; therefore market valuations largely underestimate the total value. The monetary valuation of non-economic functions of forests is desirable from the ecological point of view. Implementing this task, however, "remains difficult" (Steurer, 2000, p.4.); "remains difficult, if not impossible" (O'Connor, 2001, p.8) even at present[23]. This becomes crucial if we look at the valuation results regarding forests in the EU, for example. The total economic value of forests in the mid 90's was 430 billion ECU; 75% is the value of timber, and a quarter is the value of land (Steurer, 2000). This represents only 2.4% of the total capital stock[24] in the EU. At the same time forests and other wooded land cover over 40% of the surface area in Europe (Eurostat, 2000). Depleting for example a third of the forests in a ten-year period would barely show up in the total capital stock accounts and in the environmentally adjusted GDP, but such a large-scale loss of natural assets would have catastrophic outcomes on the ecosystem in Europe.

The monetary valuation of the degradation of natural assets and deterioration of the health of humans, usually due to pollution[25], poses even more difficulties. Regarding the environmental 'degradation cost' (including the health of humans) two main valuation methods have emerged: direct and indirect. *Direct* valuation tries to assess the actual damages in physical terms first and then tries to estimate the monetary values of these damages, therefore, it is also referred to as damage valuation. *Indirect* monetary valuation ignores damages, and only establishes a list of pollutants or activities that are thought to cause damage and calculates the hypothetical cost of avoiding these damages. The two monetary valuation methods naturally give

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[21] This, of course, was meant to be a symbolic example, since Okun's law relates unemployment and GDP already, therefore, such an idea would constitute double counting.
[22] The study also covers petroleum resources and soil accounts.
[23] Even the identification of ecological functions, themselves is difficult.
[24] With the inclusion of gas and oil reserves this ratio rises to 3.5 % (O'Connor, 2001)
[25] The word 'pollution' is used for simplification, but all environmental damaging processes are meant.

different results. A crucial point regarding monetary valuation here is, that it has to implemented at regular intervals, perhaps annually, for accounting purposes, which causes further difficulties in addition to those inherent in the valuation methods themselves.

Direct valuation

As mentioned earlier, there are different methods of valuing human life. There are numerous problems, however. Firstly, it may be difficult to prove that a certain illness is attributable to a certain pollutant; often a court has the final word. Many years may pass until the decision of the court. If the ruling establishes a cause and effect relationship between the pollution and the illness, and awards damages compensation (to be considered as the value of damage), the question is: in which year should this be recorded, which year's 'green GDP' should account for this? The GDP of the year when the pollution occurred, perhaps 10 years earlier, would be rather meaningless to adjust. The GDP of the year when the compensation was awarded can be adjusted, but what policy indication would it have 10 years after the pollution occurred? Or if the pollution that caused the illness continued for many years, should the GDP of all years be adjusted? Secondly, it is not only the court's ruling that may not come for years, but the illness itself might not show symptoms for many years, thus recording any monetary value of the deterioration of health would pose similar difficulties as pointed out above. Finally, it is not clear, how damages that result from the emission of pollutants in other countries should be recorded or how to record the damage that occurs abroad due to our pollution.

If we want to express the damages to natural assets in monetary terms we face even more difficulties. In addition to the problems above, the identification of the problem itself is difficult. Since 'nature' does not complain in the same way as humans do, many problems may go unnoticed and we might only notice the accumulated effects. Therefore, we have to be aware of the fact that by *direct* monetary valuation of damages for accounting purposes, we may well underestimate the 'cost' of damages, as many problems are either unnoticed or omitted due to insufficient proof.

Providing we identified all damages of natural assets caused by human activities, we still have to calculate the monetary values. These estimation methods are usually referred to as *costs borne* by economic agents. The costs borne by enterprises are relatively easy to identify and estimate. The valuation methods for the cost borne by households are referred to as contingent valuation method, hedonic pricing and travel-cost method (Barde and Pearce, 1991). They, either directly ask people's willingness to pay for the improvement of the environment (or willingness to accept to put up with a certain environmental loss), observe property markets or people's behaviour to estimate how much value people attach to a certain level of environmental quality. While each of these methods has its validity in some areas, "The well-known problems of applying these valuations in cost-benefit analyses at the project level[26] accumulate at the national level. At

[26] The problems are detailed in United Nations, 2000, p.42, note 9, and other places but I will pass by these,

least for the time being, such valuations do not seem to be applicable in recurrent national accounting" (United Nations, 2000, p.38.).

<u>Indirect valuation</u>

Here, the only thing that needs to be established is, that above a certain level of pollutant emission environmental damage occurs. Neither the magnitude of the damage itself, nor the emission-damage function has to be specified. The 'environmental costs' are identified as the costs that" *would* have been incurred if the environment had been used in such a way as not to have affected its future use" (United Nations, 1993: para. 50). Since this means maintaining the environment at a sustainable level, it is termed 'maintenance cost' valuation or 'maintenance costing'.

There are a large number of economic activities that would result in serious environmental damage if some steps - 'actual environmental protection' - were not taken to prevent the damage. Implementation proves that benefits exceed the costs in the case of actual environmental protection[27]. Therefore, these costs are the lower limit of the value that people attach to the part of the natural assets that was protected. The opposite, however, is not true. If an environmental protection activity is not implemented, we cannot say that people do not value the natural assets even as much as it would have cost to prevent the damage. Those people who enjoy the benefits can be different from those who have to burden the costs. Therefore, the principle behind maintenance valuation is the (hypothetical) internalisation of environmental diseconomies or disamenities. Since this is the preferred valuation method of the SEEA framework (in the light of the impossibility of the direct valuation as quoted earlier), more details will be discussed in Chapter 3.

We can conclude the same as Hanley (2000, p.26): "…there is no single macroeconomic measure of sustainability that seems satisfactory on its own." Some of the indicators suggested express welfare better than GDP, but intra-generational concerns – an important aspect of sustainable development - are only taken into account in GPI, which is adjusted for income distribution, but it is only an indicator of development but not of sustainability. On the other hand, we can also conclude that the research helps to identify those areas, which may turn out to be dead ends, and those that are worth exploring more. An example for the former one is the direct monetary valuation of environmental damage for integrated national accounting purposes. In contrast, the SMS has relatively few conceptual problems.

since as pointed out, these methods are judged not applicable anyway.

[27] Cost and benefits are not necessarily expressed in monetary terms, of course, they often are.

Chapter 2

Attempts of the 1970's

Section 2.1

Points of focus in the 1970's

Opposing views focused around GNP, its qualities, its deficiencies and its relationship with welfare. Lecomber (1978) groups the opinions into four main categories:

1. GNP was never meant to be a welfare measure; good as it is now, only fine-tuning on certain issues is necessary.
2. GNP partially measures welfare, but the common assumption is that differences in GNP are reflected in differences in welfare.
3. GNP is one component of welfare and should be considered with other components together.
4. GNP can and should be modified to result in a similar, but broader measure of welfare.

The word welfare and economic welfare are often used in literature, but the relationship is not clearly defined. Why should certain items be labelled as part of "economic welfare"[28] rather than just another aspect of welfare, another component in the welfare vector? The fact that some economic activities result in environmental damage does not mean that good environment relates to high *economic* welfare (only high welfare), or that environmental damage decreases economic welfare. Robin C. O. Matthews (1972) points out that"…economic welfare is not a special kind of welfare, it is a special means of producing welfare…" This is perhaps the major difference in views between people in the third category and in the fourth category in Lecomber's categorization.

People in the third category believe that the goods and services produced by economic activities contribute to welfare, but that aspect is already reflected in GNP. These economists advocate a broad welfare vector instead of an economic welfare indicator, and they call for more cooperation between social sciences that might have something to say about welfare (Matthews, 1972); as well as the involvement of natural scientists to prepare physical indicators regarding the state of the environment (Drechsler, 1976) to serve as complementary information.

Economists in the fourth category, however, believe that because a lot of aspects of welfare are closely related to economic activity, monetary values can be assigned to them and thus subtracted from, or added to the consumption of goods and services. Those, who advocate the calculation of economic welfare in this way, acknowledge that there are ambiguous points about

[28] The problem here is the lack of clear definition for economic welfare, perhaps the criteria is that it includes things that can be measured in money, but this itself is ambiguous

the imputation of monetary values, but they do not view these as conceptual difficulties. They point to underdeveloped theories and practical difficulties.

Some government expenditure items are suggested for exclusion on the basis that they are either intermediate or defensive expenditures, which only aim to keep welfare at the current level. The cost of environmental damage should be calculated and deducted. On the other hand, the imputed monetary values of leisure, housework, services from governmental capital stocks and from consumer durables should be added[29].

Two representative concepts, both in the early 70's, the Measurement of Economic Welfare (MEW) by Nordhaus and Tobin, and the Net National Welfare (NNW) by Japanese scholars will be analysed in the following two sections.

Section 2.2

Measure of Economic Welfare of the United States

In 1972 William Nordhaus and James Tobin published a paper titled "Is growth obsolete?" in which they made an attempt to provide an extensive measure of output that is welfare related, and termed it Measure of Economic Welfare (MEW). They point out that MEW is not intended to be an indicator of overall welfare, for a broad picture social indicators would also have to be observed. There aim was not only to construct a measure of economic welfare, but also to look at its relation to economic growth as measured by the increase of GNP or NNP. In addition to the construction of MEW, Nordhaus and Tobin devoted a section to the relationship between natural resources and growth, and another one to the effects population growth. Here, I will concentrate on MEW, as this has the most implications regarding the development of integrated accounting.

The aim was to produce an indicator where consumption was in the focus. Because consumption represents a large part of GNP, the calculation of MEW also takes GNP as its starting point. Items excluded from GNP expenditure, on the basis that they are intermediate, are either considered *capital investments,* such as heath and educational expenses, money spent on road construction, consumer durables, etc; or *instrumental,* also called "regrettables", that are expenses only to keep social order, national security or the environment at the current level, such as the services of the police force, sanitation services, etc. In addition to the changes made to the items included in GNP, new categories are added, the monetary value of which are either added or subtracted. These categories are leisure time (+), non-market (household) work (+), imputed services of private & government capital (+), and disamenities due to urbanization (-).

In the case of the United States, a large part of defensive expenditures were, in fact,

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[29] In exchange, expenditures on consumer durables were excluded to avoid double counting.

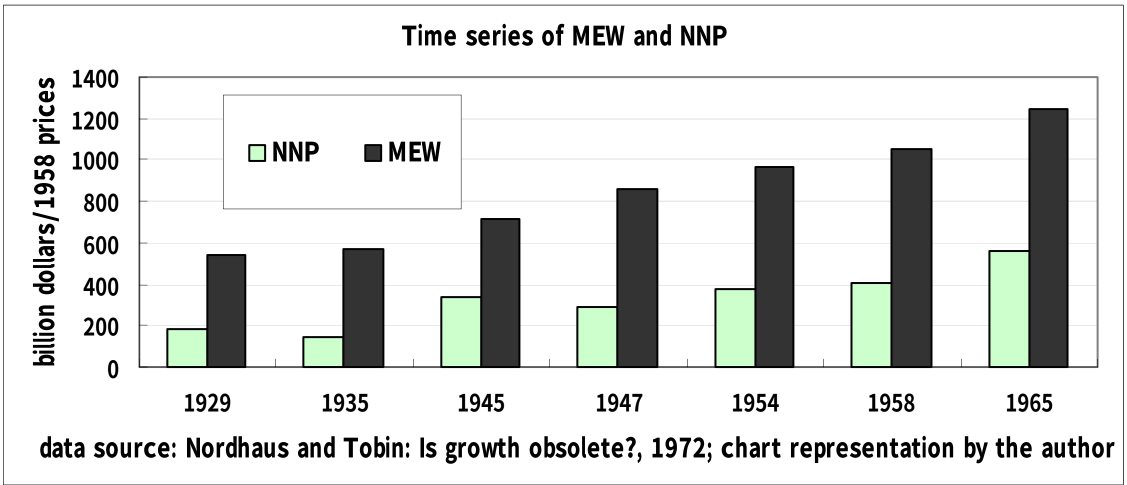
national defence[30] expenditures and represented a considerable share of government purchases. These were recorded as regrettables. Defensive environmental expenditure was recorded in the ‘intermediate goods and services’ category. The only environmental related expenditure considered was ‘sanitation’. The total amount deducted was 30% of all government expenditures before WWII, more than 90% under the war and around 60% after the war.

As for the valuation of services from wealth, estimates from an earlier study were used. The value of leisure and household work were imputed using its opportunity cost, the forgone income. The total monetary values of leisure and non-market activities were estimated to be more than twice of personal consumption.

Living in a densely populated city brings about amenity losses resulting from noise, litter, traffic congestions, pollution, and visual amenity deterioration. It is also a fact that the wage rate is higher in cities than in rural areas. Nordhaus and Tobin saw this wage differential as a “disamenities premium” for living in a less pleasant urban surrounding. They allowed for an estimated equilibrium zero-migration differential, for other reasons resulting in wage differences, and reasons for choosing a residential location other than the wage level. Data on population density, per cent urbanization, and disposable personal income from four states in the US were the basis of the computation, which targeted the period between 1929-65. Disamenities adjustment came to a significant 8% of average family disposable income, this 8% correction, however, remained throughout the observed period, despite more people living in denser urban areas.

MEW estimates compared to NNP are shown in Chart 2.2-1. While NNP showed some fluctuations, MEW was gradually and steadily growing, even at times when NNP fell.

Chart 2.2-1 Time series of MEW and NNP in the United States



While NNP per capita grew 1.7% annually during the observed period, MEW only increased 1.1%. The result was partly an answer to the ‘antigrowth men’: “Yet MEW has been

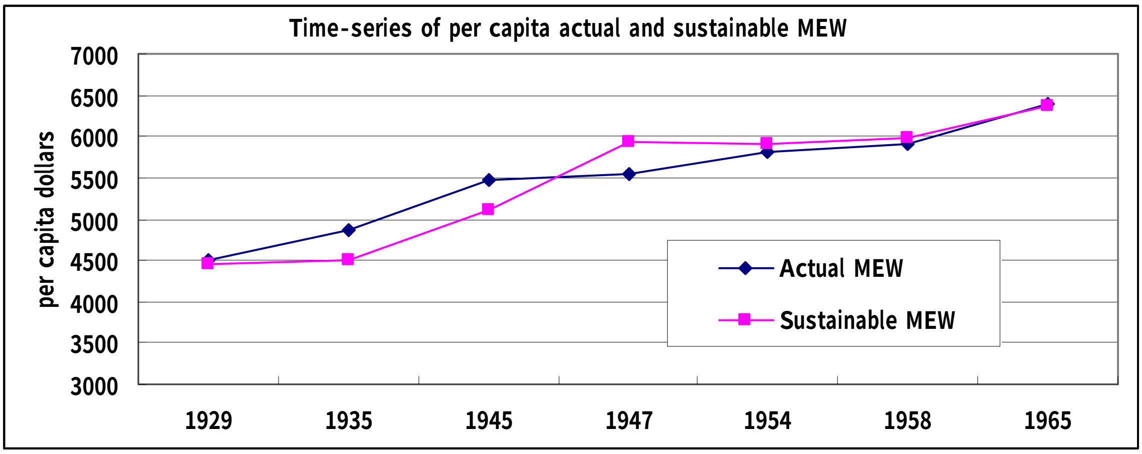
[30] The words “defensive expenditures” and “defence expenditures” are similar, but the former refers to all spending by which the occurrence of something negative is avoided or prevented, whereas the latter exclusively refers to military spending.

growing. The progress indicated by the conventional national accounts is not just a myth that evaporates when a welfare-oriented measure is substituted"(p. 13)[31].

Regarding the environment, negative "externalities" of economic growth were associated only with urbanization. Nordhaus and Tobin gave the reason for this (p. 46) "If we had estimated of the value of environmental capital, we could add them to the national wealth estimates of Table A.3[32] and modify our calculations of MEW net investment accordingly. We have not been able to make this adjustment, but given the size other components of wealth, we do not believe it would be significant."

There is an important point that connects this study to the present discussion of sustainable development. Nordhaus and Tobin prepared two MEW estimates, one 'actual MEW', the other one 'sustainable MEW'. The latter one does not only include the net investment into the reclassified capital categories, but also provisions to guarantee that the per capita consumption would grow with rate of technological progress in the standard neoclassical growth model. This requirement is much stronger than the present concept of sustainable development, which only states that the future generations should be at least as well off as the present generation. Nordhaus and Tobin conclude that if 'actual MEW' is higher than 'sustainable MEW' we are living up the wealth of future generations, whereas, if it is the other way round and 'sustainable MEW' is higher, we are making even more provisions than necessary. According to their calculations the sustainability condition was met or nearly met after WWII (Chart 2.2-2).

Chart 2.2-2 Time-series of per capita actual and sustainable MEW



Data source: Nordhaus and Tobin: "Is growth obsolete?", 1972, representation by the author

31 This and further quotations of this section are from: Nordhaus and Tobin: Is growth obsolete? NBER, 1972

32 Table A.3 is Net Stock of Public and Private Wealth for the years observed. It includes Net reproducible capital, Non-reproducible capital (mainly land), Educational capital and Health.

How do they answer their own question? “Is growth obsolete? We think not.” (p. 24). They emphasize that while GNP is not a perfect indicator of welfare, the general picture of economic growth that it indicates remains, even after it is adjusted to reflect welfare better. The importance of Nordhaus and Tobin’s work is that they shed light on the dark side of economic growth, more precisely of certain economic processes, without denying its achievements. We may say, however, that the direct contribution of the MEW concept to integrated environmental and economic accounting approaches of today is limited. The disamenities due to urbanization are only one dimension of environmental problems. Also, the applied valuation method ignores those environmental concerns that equally effect people regardless whether they live in urban or rural areas, therefore not reflected in wage differences.

As a matter of fact, to construct a system that future statistical work can be based on was not Nordhaus and Tobin’s aim in the first place (Matthews, 1972). Abramovitz (1972) aptly summarizes the *importance of the essay*: “…to stimulate economists to renew work on the improvement of out national product estimates, to make them more useful as a basis for the study of growth and for judgements about its value. In that sense the Tobin-Nordhaus procedures are more important than their conclusions.”

Section 2.3

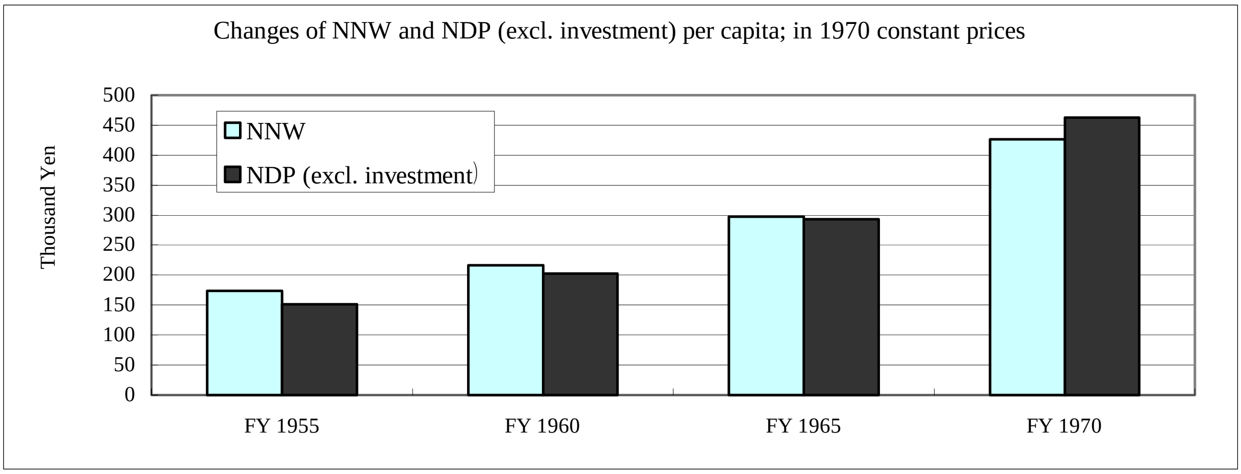
Net National Welfare, the Japanese approach

The NNW Measurement Committee published its report in 1973. The aim was the construct a macro indicator that expresses welfare in monetary terms better than GDP, the same goal as we saw in the previous section. The necessity of such work in Japan was prompted by the large-scale environmental damage, especially in the form of industrial pollution, partly attributed to the high economic growth and rapid industrialization. NNW was constructed with welfare as a flow concept in mind. As a result, investment is not a factor in NNW since it does not contribute to welfare in the year when the investment was made. This point is different from MEW.

The construction of NNW, however, the items included and excluded, are similar to MEW. There were two major differences in the structure: environmental maintenance costs were shown separately, and losses due to pollution were also presented as a separate category. Monetary values of environmental costs caused by pollution, were imputed and recorded as a negative item. In addition to conceptual problems with valuation methods, the unavailability of sufficient data on emissions, and the lack of environmental standards forced the Committee to restrict their calculations, and introduce several assumptions. Although the valuation of environmental damage itself (direct valuation) was said to be desirable, due to underdeveloped methodology of valuation methods of this sort and due to the lack of data on damages, maintenance cost valuation was chosen. The hypothetical cost of cutting back pollution to a defined level were computed and recorded as negative values.

Estimates were computed for Fiscal Years (FY) 1955, 1960, 1965 and 1970 (Chart 2.3-1). While in 1955 NNW was estimated to be nearly 13% higher than NDP (excluding investment), NNW could not keep the pace with the high growth rate of NDP and in 1970 NDP was approximately 8% higher than NNW. The growth rate of NDP was considerably higher, 4.9% annually, whereas the growth rate of NNW came to only 2.4% annually.

Chart 2.3-1 Time-series of NNW and NDP in Japan



Source: NNW Measurement Committee, 1973. Measuring Net National Welfare of Japan.

To understand why the growth rate of NNW lagged behind that of NDP, we have to look at the different factors that compose NNW, and see how they changed over time (Table 2.3-1).

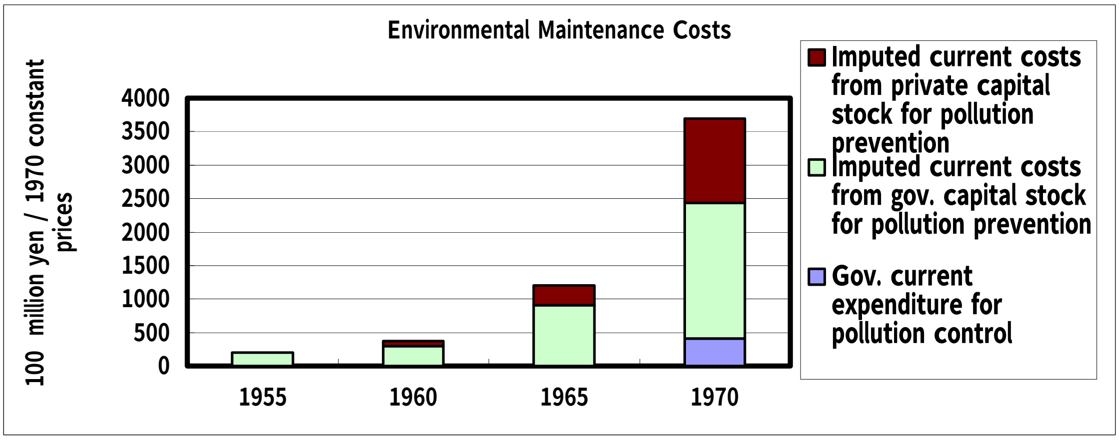
Table 2.3-1

	Percentage Composition (%)				Average Annual Growth Rates (		
Item/Fiscal Year	1955	1960	1965	1970	1955/1960	1965/1970	1970/1975
①NNW - Government Consumption	7.7	6.8	7.7	6.9	2.8	10.4	6.1
②NNW - Private Consumption	67.3	72.8	75.9	74.1	7.1	8.6	8.1
③Services from Government Capital Stock	0.9	1.0	1.5	2.0	9.4	15.9	14.8
④Services from Personal Consumer Durab	0.6	1.0	2.6	5.8	16.3	31.4	27.3
⑤Leisure Hours	14.4	14.3	14.0	14.2	5.3	7.1	9.0
⑥Non-Market Activities	12.3	12.5	13.4	14.4	5.6	9.3	10.2
⑦Environmental Maintenance Costs	▲ 0.1	▲ 0.2	▲ 0.4	▲ 0.8	13.3	26.3	25.2
⑧Environmental Pollution	▲ 0.2	▲ 4.6	▲ 11.6	▲ 13.8	93.4	29.2	12.6
⑨Losses due to Urbanization	▲ 2.8	▲ 3.6	▲ 3.2	▲ 2.7	10.6	5.0	5.2
NNW	100.0	100.0	100.0	100.0	5.4	7.7	8.6
NDP (excl. net investment)					7.0	8.7	10.8
Source: NNW Measurement Committee, 1973. Measuring Net National Welfare of Japan, edited by the aut							

Although the annual growth rate of the imputed services from consumer durables stand out, the growth rate of imputed losses due to environmental pollution were even more striking until the mid 60’s. Regardless the theoretical foundation of the valuation method used in imputing these values, they reflect the reality in Japan in the 50’s and 60’s. During these years people started to be able to afford the so-called "white goods[33]" as well as their first cars, hence the high growth rate of services from consumer durables. At the same time, thousands of people fell ill or died as a result of serious industrial pollution incidents

The environmental maintenance costs were calculated by adding up three different components. (a) Government current expenditures for the pollution control. Data was not available before 1967, but the amount was considered to be negligible, anyway. (b) Current costs imputed from capital stock for the prevention of pollution of the government sector, covering sewage and excrement treatment as well as domestic wastes. (c) The same as (b) for the private sector, covering air and water pollution areas, treatment of wastes, etc. Environmental maintenance costs in 1970 were 15 times of those in 1955. The share of the private sector to cover these costs increased to approximately one third. This is the result of stricter environmental regulations following several serious industrial pollution incidents.

Chart 2.3-2 Environmental Maintenance Costs

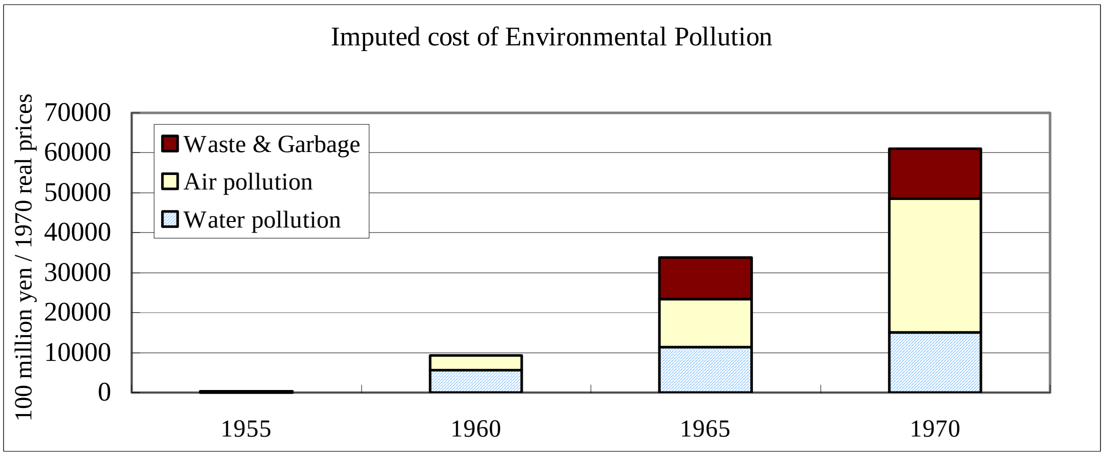


Data source: NNW Measurement Committee, 1973. Measuring Net National Welfare of Japan, chart representation by the author

Environmental pollution was divided into three main categories: water pollution (BOD[34]), air pollution (SO_X, soot&dust, NO_x, CO, HC), industrial waste & domestic garbage. In the case of waste, garbage and dust&soot the total amount of emissions were thought to cause environmental damage, while the emission level of 1955 was set as an environmental standard for other substances. There were no official environmental standards at the time in Japan. Costs were imputed to the difference between these target levels and the annual emissions by computing the annual hypothetical costs of the most efficient "appropriate treatment" of pollutants (maintenance cost valuation). Imputed cost of environmental pollution came to a staggering 6000 billion yen annually in 1970 (Chart 2.3-3), more than 16 times of actually spent environmental (imputed) maintenance costs; and twice as much as the government consumption in NNW.

[33] This refers to large, electrical household appliances, such as washing machines, refrigerators, etc.
[34] Biological Oxigen Demand

Chart 2.3-3 Imputed Cost of Environmental Pollution



Data source: Same as Chart 2.3-2

By 1970, air pollution was responsible for more than half of the imputed environmental costs, as well as showing the highest rate of increase during the observed 15-year period. Although SOx accounted for more than half of those imputed costs, the rate of increase concerning exhaust gases from internal combustion engines stands out.

How do NNW results compare to those of MEW? On the one hand, conclusions that were drawn from the two trial estimates are very similar. In both countries the growth rate of the welfare indicator was lower than the growth rate of the national product, 1.1% and 1.7% respectively in the US, and 2.4% and 4.9% in Japan[35]. On the other hand, NNW was nearly the same as NDP in Japan, whereas MEW was more than twice of NNP in the USA. The reason is that the monetary values of leisure and non-market activities represent a far greater portion in MEW than in NNW. This is the result of the different calculation of time devoted to these activities.

As for the contribution of the NNW experience to our present frameworks is perhaps more than that of the MEW. The database for estimates was compiled regarding observable or measurable phenomena. The Committee tried to create a statistical framework, rather than come up with one-time estimates. It was, however, specific to Japan in the way, that it did not include natural resources. The idea of sustainability did not receive much attention in the report, not even as much as NDP itself means sustainability[36]. The reason cited in the report was the short period of 15 years covered; during which sustainability concerns cannot be observed. The idea to value environmental damage by the maintenance cost valuation method was carried over to the SEEA framework. Recording environmental expenditure separately from other expenditure categories is also kept.

As far as the integration of accounting systems is concerned, many question were left

[35] Percentage changes mean annual real changes per capita, and refer to the periods that were covered in each study. 1929-1965 in the U.S. and 1955-1970 in Japan, MEW or NNW respectively.
[36] NDP excluding investment was the preferred indicator of committee for comparison.

unanswered in the 70’s. In fact, such integration was not mentioned explicitly. It became clear, however, that one factor that clearly diminished the growth rate of MEW and NNW compared to NDP was environmental deterioration and disruption. Measured by directly (MEW) or indirectly (NNW) this factor reached 5-10% of the NNP /NDP.

Chapter 3

Frameworks of the 1990's

Section 3.1

Points of focus in the 1990's

Three fundamental differences between the debate in 70's and in the 90's can be identified. Firstly, research on the relationship between the environment and economic activities received international attention and support from the United Nations and other international organizations; as well as more, official recognition at national level.

Secondly, the arrival of the concept of sustainable development put the research in a comprehensive framework, directly calling for deeper interdisciplinary and multidisciplinary work. Debate only among economists will not result in policies that help to reach a sustainable path. In addition to intra-generational issues, intergenerational considerations have received equal weight.

Thirdly, the aim is not (only) to alter GDP and construct a different supplementary indicator. Integration has become the key world, and it covers many areas, such as policy integration, and the integration of accounting systems, from which valuable information can be drawn, among them new indictors.

Some ideas were carried on from where they were left in the 70's, and followed the footsteps of the NNW framework. The SEEA framework, which continued the 'tradition' of monetary valuation by maintenance costing, and the NAMEA framework, which broke with the monetary valuation approach, will be reviewed in this chapter.

Section 3.2

Satellite System of Integrated Environmental and Economic Accounting

Development and present status of the SEEA

The integrated accounting system that has received wide international attention in the past decade is the (Satellite) System for Integrated Environmental and Economic Accounting (SEEA) prepared and published in 1993 by the United Nations Statistics Division (UN, 1993/a). The suggested system was meant to be an eclectic approach, trying to balance the opposition of different concepts: "The main task of the handbook is to effect a *synthesis of the approaches of different schools of thoughts* in the fields of natural resource and environmental accounting" (UN, 1993/a p.1, emphasis added). Pointing to the fact that the research was in a preliminary stage, the handbook was termed '*Interim version*'. The 'Interim version' is unnecessary complicated, gives few practical suggestions on implementation and says almost nothing how it should be applied in policy making. It leaves the door open to choose from several 'versions' of SEEA, but it was clear from the beginning that some of them were impossible to implement in practice. Nevertheless, 11 countries[37] tried to implement at least some parts of the SEEA. It is interesting, however, that only 4 of these countries are in the OECD and no European country was among them. This is surprising, considering that the EU is well known for taking environmental issues seriously. Still, some valuable experience collected from the reports of the trial estimates, and ongoing debate about the concept resulted in the United Nations publishing a much clearer and simplified handbook of the SEEA, termed *'An Operation Manual'* in 2000 (UN, 2000). It reflects on the country experiences, acknowledges that some parts of the 'Interim version' are practically impossible to implement, as well as it gives a "step-by-step" guideline on implementation, provides some examples, and details on possible policy use.

Concept and structure

The environment contributes to human welfare in two main ways: indirectly by providing resources into production, and assimilating part of the emission and waste that are generated through production and consumption; directly through maintaining the ecosystems on earth, which humans are part of, regulating the climate; and providing direct enjoyment through amenity, aesthetic appreciation, and providing space for recreation. Both environmental stocks, and flows of environmental services & goods are important contributors to welfare. If the standard structure of the SNA was to be extended by environmental dimensions, it should contain both flow accounts and stock accounts. At least this was the original idea in the 'Interim version'. This would mean expanding the asset boundary of the SNA to include environmental assets, and expanding the production boundary to include goods & services of the natural environment. The latter, however, was judged to be difficult to implement, reflecting on the fact that none of the country-estimates tried to expand the production boundaries[38]. Monetary valuation methods, such as contingent valuation, hedonic pricing and the travel cost method have serious theoretical controversies, and are unsuitable for regular national accounting purposes considering the immense costs involved. The flow accounts are, of course, affected to the extent of change in the environmental assets by depletion or degradation (pollution).

The SNA already includes those natural assets that are economic assets: over which proper rights are enforced *and* from which economic benefits maybe derived. In the SEEA, in addition to these, all those natural assets are included that "function as providers not of natural resource inputs into production but of environmental services of waste absorption, ecological

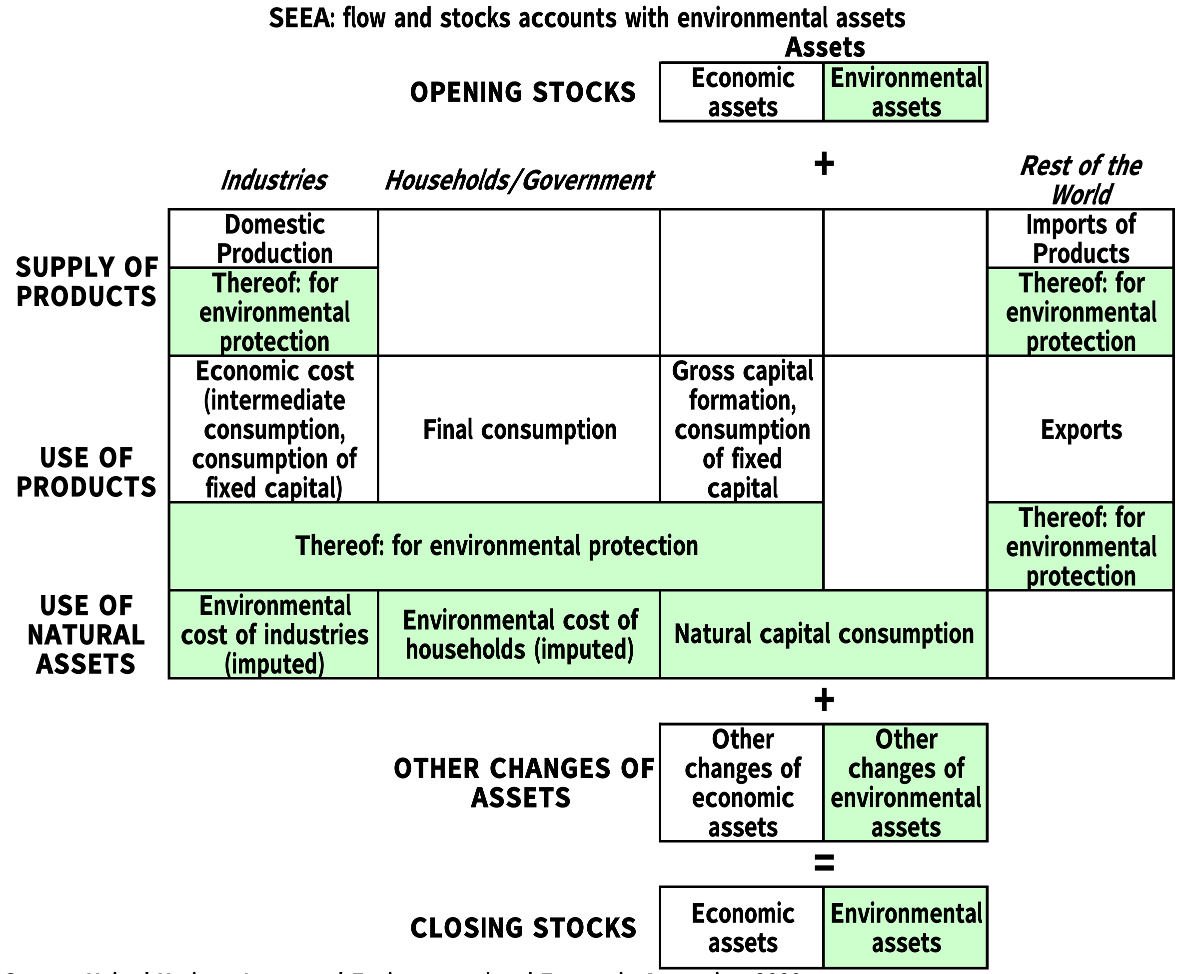
[37] Canada, Colombia, Ghana, Indonesia, Japan, Mexico, Papua New Guinea, the Philippines, the Republic of Korea, Thailand, and the United States of America. (UN, 2000)

[38] In the 'Interim version' the expansion to include household production and its environmental effects was also suggested, but dropped in the 'Operating Manual'.

functions such as habitat and flood and climate control, or other non-economic amenities such as health and aesthetic values” (UN, 2000, p.26). Natural assets are recorded in physical units first and monetary valuation is implemented, where it is possible.

Only subsoil assets (proven reserves) are covered fully by market prices. Other assets, such as biological assets, land and water have functions that are not covered by the market price and air does not even have a partial market price. Although the monetary valuation of the non-market functions was suggested in the ‘Interim version’, this was given up in the ‘Operating Manual’ in light of the controversies regarding the valuation methods[39]. Physical and monetary changes due to depletion are to be calculated for those assets that have at least a partial market price, and degradation is to be recorded in physical terms for those functions that do not have a market price and monetary values to be imputed by ‘maintenance costing’. The adjusted accounts are represented in Chart 3.2-1.

Chart 3.2-1 Flow and stock accounts in the SEEA



Source: United Nations: Integrated Environmental and Economic Accouting, 2000

39 These would be the contingent valuation method, hedonic pricing, and the travel cost method.

Environment related expenditure, referred to in earlier chapters as 'defensive expenditures, is also shown separately.'[40] They show by sector, how much effort was made to keep the environment at the current level. If the share of these expenditure items is high in the GDP, we may conclude that we have (or the sector has) a very environment damaging economic structure, which appropriates such high environmental protection expenditure. Or, we may conclude the opposite, i.e. a lot of effort is made to protect the environment and probably little damage is done. These statistics have to be compared to the changes in emission over time, and the 'maintenance' costs' of these emissions. Other uses include assessing the actual costs borne by industries and see how it affects their competitiveness, and identifying business opportunities in the environmental protection industry.

The chart demonstrates how supply & use accounts are interrelated with the asset accounts. It also shows human induced and natural changes in environmental assets. The changes due to human activity are recorded as imputed costs, including both depletion and degradation. Imputed monetary *costs of depletion,* and also the value of stock are calculated by the net price or the user cost allowance method[41]. These methods, of course, do not account for the value of non-economic functions of renewable environmental assets, as it was pointed out earlier. As for the *cost of degradation* of the environment, the 'maintenance cost method' is advocated by the SEEA. These are expenses that *would* have been incurred during the accounting period to avoid or mitigate the environmental damage that was actually caused. The rational behind it is the internalisation of the social cost of pollution that is currently not paid by the polluters. In the handbook, there are two more points mentioned in support of maintenance costing. Firstly, if we look at environmental stocks as inputs into the economy, and also absorbing part of the output (pollution), then the diminished capacity of the environment to provide these functions can be considered as the depreciation of these assets. Thus, (hypothetical) expenditure to keep these functions intact can be regarded as capital maintenance; consequently it can be subtracted from GDP. Secondly, if these costs were incurred by economic agents, that would mean meeting the environmental standards, thus guaranteeing strong sustainability. It has to be noted, however, that if certain functions of the environment get damaged, they cannot be replaced by buying or making 'another one' as man-made capital can. In fortunate cases they can be restored, but these costs might well exceed those calculated by the maintenance cost method.

Finally, chart 3.2-1 is an easily comprehensible representation of the flow and stock

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40 Environmental protection expenditures do not cover all defensive expenditures; they include several other expenditures that are meant to maintain the socio-economic and natural environment, as it was discussed in the previous chapter.

41 Net price method estimates the value of a resource at the beginning of a period by multiplying the volume of total extractions during the lifetime of the resource with the difference between its unit market price and the unit cost of production. The user cost method calculates the difference between net returns from the sales of an exhaustible resource through its lifetime and the "perpetual income stream" that that results from the investment of the user cost at a given interest rate.

accounts, but it does not indicate any unit of measure. One would assume that it is in monetary units, since it is integrated with accounts of the SNA. But monetary valuation of the stocks of several environmental asset categories is not possible, while in other cases non-economic functions of assets are ignored. For these in particularly, and also for other natural assets a 'changes in quality' account (in physical units) is attached after, but separated from, the asset accounts.

Versions

The SEEA is a flexible system to accommodate all sorts of views and options. The' Interim version' contains 6 main versions of the SEEA; some of these also have subversions. Some of the versions were difficult or impossible to implement, thus termed 'not suggested' in the 'Operating Manual'.

Version I represents the basic structure of the SEEA. It is derived from the SNA's supply&use and asset accounts. It details environmentally relevant information, while others are presented at an aggregated level.

Version II explicitly shows environmentally related flows and stocks already included in the national accounts by following the Classification of Environmental Protection Activities (CEPA).

Version III is the accounting section of the SEEA in physical terms: material/energy balances, natural resources accounts and residual flow accounts.

Version IV is the part where monetary valuation is introduced. In the 'Interim version' three valuation methods were suggested: (1) market valuation, (2) maintenance cost valuation, (3) market valuation + damage valuation. The last one, version IV.3, was judged to be impossible to implement, thus not suggested in the 'Operating Manual'. Maintenance cost valuation concept was mention earlier, but details on implementation are as follows:

Five measures are listed under 'maintenance' activities (UN, 1993/b, paragraph 307):

- reduction or abstention from economic activities
- substitution of outcomes (producing substitutes or changing consumption patterns)
- substitution of inputs (applying new technologies, etc.)
- prevention (end-of-pipe technologies)
- restoration

The first three together are also referred to as avoidance. In principle, the SEEA states that out of these five options the cheapest one has to be applied, thus following economic efficiency.

It is, however, not always straight forward which calculation method provides the cheapest result. Choosing the method has a large subjectivity element. The applied method may change with technological advancement or for other reasons from one accounting period to another, making calculation rather tedious. In reality a combination of these methods would give the cheapest, most efficient result. The calculation of this, however, is a complex modelling exercise.

Maintenance costs become cheaper with technological development, therefore, environmental costs seem to be less and less in a time-series analysis, despite the fact that perhaps nothing happened in reality and the depreciation of the environment is the same. Since there is a difference between private damage cost and social damage cost, the problem will not be solved by economic cost considerations only, until this difference exits. Without the introduction of certain policies (such as environmental taxes, etc), which make this difference disappear, the pollution may continue until maintenance costs become virtually zero[42]. An additional technical difficulty when calculating green GDP ex post is, that we cannot, or at least should not, apply present technologies to calculate maintenance costs of decades ago. There are no guidelines on how to implement ex post green GDP calculations regarding maintenance costs.

Finally, an important point regarding monetary valuation: *"hypothetical maintenance (avoidance/prevention) costing is probably the furthest environmental accounting systems can go in providing aggregate (weighted in money terms) information on environmental impacts from economic activities."* (UN, 2000, paragraph 33). This is to say, that either we accept maintenance costing as the way to impute monetary values to environmental degradation (pollution), or we refrain from monetary valuation of pollution costs. The SEEA advocates implementation.

Version V, the expansion of production boundaries, is not suggested for implementation in the 'Operating Manual', as pointed out earlier.

Adjusted aggregates

It is probably fair to say that the SEEA was designed with the final aim to calculate 'green aggregates' by imputing costs to both environmental depletion and degradation and deducting them from NDP and capital formation[43].

The environmentally adjusted accounting identities become:

$O + M = IC + C + CF + X$

Goods and services produced (O), import (M), intermediate consumption (IC), final consumption (C) capital formation (CF), export (X)

Value-added (environmentally adjusted) identity for industry i:

$EVA_i = O_i – IC_i – CC_i – EC_i = NVA_i – EC_i$

fixed capital consumption (CC), environmental costs (EC)

Domestic-product (environmentally adjusted) identity for the whole economy:

$EDP = \Sigma EVA_i - EC_h = NDP – EC = C + CF + X - M - CC - EC$

The calculation of two different environmentally adjusted domestic products (EDP) is possible.

- ✧ EDP_1 = NDP – resource depletion costs (only market based valuation, version IV.1)
- ✧ EDP_2 = EDP_1 – degradation costs (market based valuation + maintenance cost valuation,

[42] More precisely, the pollution will continue as long as the private marginal damage costs are lower than the marginal abatement costs.

[43] This is not to say that SEEA has no other possible uses.

version IV.2)

In addition to these, the most commonly quoted indicator is the environmentally adjusted net capital formation ECF = CF-CC-EC, or the similar genuine saving indicator, where savings are adjusted by the same environmental costs as the capital formation[44].

The SEEA emphasizes that these adjusted aggregates can give a more realistic picture of the wealth, wealth formation and consumption of a country. Rao (2000, p. 220) states that "Conventionally, 'green' NNP is the maximum amount of produced output, that can be consumed at a point in time while leaving this measure of wealth constant, and genuine saving is the difference between green NNP and consumption." The 'Operating Manual' also points out that EDP and other adjusted indicators can be used for the same main purposes as GDP, namely international comparison, breakdown by economic sector, and growth calculations from a different prospective.

Policy uses

The SEEA categorizes possible policy application in three groups:

✧ Application to economic policy
✧ Application to environmental policy
✧ Implications for policy-making

Application to economic policy

The first step is to assess, or rather reassess, the economic performance of a country with the help of the EDP. In the future EDP figures should be used to compare sustainable economic strength, allocate development aid, and evaluate investment opportunities, stated in the SEEA. It is not clear, however, how the purchase power parity should be used for comparison, since the imputed costs of the environment are a factor in EDP, but not included in the market basket. Moreover, the calculation of maintenance costs may be based on technologies and production processes that would have to be imported first which would change the external balance of a country, possibly effecting its exchange rate, etc. ECF, genuine saving, and a large number of supplementary indicators - mainly ratios between new and traditional indicators - can be prepared and used in the analysis. After performance evaluation, the next step is to reform economic policies. These should concentrate on internalising the social cost of depletion and degradation by the introduction of environmental taxes, effluent charges, tradable pollution permits and abolishing environmentally harmful subsidies. Sectoral breakdown of imputed environmental costs is necessary to assess the economic impact of such policies. The final step is the evaluation of policy effects. This would be done by the analysis of the change in environmentally adjusted indicators, their ratio or gap compared to traditional indicators together with the assessment of other

[44] The difference is, that in genuine saving the foreign financing of capital formation is not allowed.

macroeconomic indicators.

Application to environmental policy

Information gained from the SEEA alone is insufficient to assess the state of environment and to design policies. Supplementary systems, such as the DSR (UN, 1999) are necessary. Nevertheless, data from the SEEA can be used to set up environmental priorities and identify those industries and activities that put pressure on the environment. Input-Output analysis should be implemented to find the original sources of the pressure. Based on this information environmental policies can be outlined. The last step in the implementation is checking the results with the help of indicators in the SEEA and DSR.

Implications for policy-making

This is a broad issue, where the key point is that accounting should not remain a technical exercise, but “stakeholder”, parties that are effected, should be involved in the process. This would include identifying priorities and the basic questions that integrated accounting should answer; deciding what environmental assets should be accounted for and to what extent; design policy measures based on the careful analysis of the results and check if they worked and to what extent. In addition to these, recorded transboundary pollution flows can serve as the basis of international negotiations.

SEEA experiences

Some of the results below are not necessarily from country estimates, but from case studies involving several countries. The methodology and the indicators however, are identical to those in the SEEA.

The study (Repetto et al, 1989) accounting for Indonesia’s natural assets was briefly mentioned. It revealed that while GDP growth averaged 7.1% annually between 1971-84, “NDP” only increased 4%. “NDI” shows an even grimmer picture, being negative for two consecutive years[45]. Petroleum, forests and soil were covered in the study. The conclusion of the paper is that Indonesia is living up its natural resources for the short-term interest of rapid growth.

To express the relative magnitude, ECF is often expressed as the percentage of GDP (GNP, NDP). In different study from Repetto's regarding Indonesia, this indicator was *negative* from 1970-81 (positive from 1982-84), in Ghana 1991-93 (Bartelmus, 1999), and in Mexico in 1985 (Bartelmus, 1994). The similar genuine saving indicator was negative for Sub-Saharan Africa from 1977 to 1992 (and mostly positive between 1961-76) (Hamilton, 1994), in the Philippines for the agricultural industry from 1970-83 (Kojima, 1997). All these negative ECFs indicate

[45] The original notations are used, but “NDP” is the same as EDP^*, and “NDI” is the same as ECF^*. The star is to indicate that while calculated depreciation of natural assets were deducted; depreciation of man-made capital was not.

non-sustainability, since total productive capital is diminishing.

What can we say about *positive* ECF results? Through the whole period observed, the following countries had positive environmentally adjusted capital formation: Korea (1970-88), Japan (1970-95), U.K (1980-90)[46], Philippines (1988-93) (Bartelmus, 1999) and Papua New Guinea (1986-90) (Bartelmus, 1994). Similarly the genuine saving index was positive in OECD countries (average) (1961-91) (Hamilton, 1994). These results show that developed countries meet the conditions of weak sustainability. On the other hand, it is also possible that not enough environmental assets were included, the market prices were highly distorted, the valuation method was not appropriate which resulted in positive indicators. Nevertheless, “long term weak sustainability” probably means non-sustainability regarding the original concept of the sustainability. Kojima (1997) arrives to a similar conclusion by analysing forest assets and the timber processing industry in Indonesia.

In a number of projects that calculated EDP[47] for South-Asian countries serious adjustments had to be made to GDP due to unsustainable resource depletion (Kojima, 1997). All studies, however, showed an increasing EDP, moreover, the rate of increase exceeding that of the GDP. Unsustainable resource depletion was not reflected in the EDP. Several economists (Simon, 2000; Hanley, 2000) point to the lack of relationship between EDP and sustainability.

In the Philippines, the trial estimates (Domingo, 1998) covered three natural resources: *fishery resources*, *forestry resources* and *mineral resources*[48], but they did not account for pollution. The results are surprising. The observed period was between 1988-92. In 1988 EDP was about 3.7% less than NDP[49], in 1992, this difference shrank to 0.36%. This means that the growth rate of EDP was considerably higher than the growth rate of NDP[50]. Environmentally adjusted capital accumulation (ECF) estimates showed similar improvements. The general conclusion of the project is: “Total net accumulation of produced and non-produced economic assets has been positive in the Philippines, indicating at least weak sustainability (of overall capital maintenance) of economic activity in the country” (Domingo, 1998, p.94). In the meantime, fishery resources depletion totalled 1.3 million tons[51]. The stock of ‘old growth dipterocarp forests’ decreased 38% in 5 years. The stock of ‘second-growth dipterocarp’ forest decreased 25%. Mineral resources decreased only 0.07% due to little extraction and positive ‘other accumulation’ items. The SEEA estimates may indicate weak sustainability, but the Philippines will soon end up without forests and fish stock. One reason why these trial estimates lead to such controversial results is that

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[46] In another study (Pearce, 1993) adjusted net savings were only positive after 1985, and slightly below zero before that.
[47] In the studies that Kojima (1997) overviewed, some projects calculated green GDP, while others green NNP or green NDP.
[48] Limited to non-cultivated marine fish stock and some metallic minerals.
[49] Difference expressed in percentages of the NDP
[50] The growth of EDP was 1% higher than GDP in each year, except 1991, when they were equal.
[51] Stocks were not estimated. Numbers quoted here are rounded to the nearest million.

current prices were used; as El Serafy (1997, p. 221) pointed out: “When current prices are used for stock valuation, and the changes in stock values are incorporated in the flow accounts, the integrity of the latter is damaged and very little *environmental* wisdom will be gained from such a procedure, and even less *economic* insight”.

In the Korean project (Kim at al, 1998) the observed period was between 1985-92, and covered both natural assets and emission flows. The main adjustment to NDP came from degradation costs, which were imputed using maintenance costing. The EDP was 3.08% lower than NDP[52] in 1986. This gap closed and in 1992 the difference was 2.01%. Therefore, in Korea too, the rate of increase of the EDP exceeded the rate of increase of the NDP. Environmental costs were allocated to industrial sectors. The only industries that had a larger than average share in environmental costs were the ‘Electricity, gas and water’ in 1986, the ‘Electricity, gas and water’ and ‘Mining’ in 1992. This is not surprising, since air pollution was the largest contributor (98%) to environmental costs, probably due to expensive technologies when imputing maintenance cost[53]. The report concludes: “This might indicate that these industries have a larger environmental impacts than the others.” (Kim, 1998, p. 75) This may be true, but we have to be cautious with putting all the blame for environmental problems on these industries in Korea. 83.5% of Korea’s electricity production comes from nuclear power, the largest share than in any other country in the world (OECD, 1999)[54]. This may cause other problems, but contributes little to air pollution. Only 8.5% of electricity production comes from fossil fuels (coal). On the other hand, the ‘Manufacture of chemical products’ category contributes less than average to environmental costs. Most serious environmental problems, both air and water pollution, in Korea, however, are in the Ulsan-Onsan Industrial Complex region, which is centre of chemical and heavy industries (Japan Environmental Council ed., 2000). The Korean estimates fail to point to these environmental problems.

Despite the best intention of the experts involved in the projects, none of the estimates included enough environmental problem areas and pollutants so that any meaningful conclusion can be drawn. Estimates fail to pinpoint serious environmental damages, and it also remains unclear where do we have to go from here. Many environmental concerns were not included either because there were not enough data, or monetary valuation was impossible. In addition to these limitations, the monetary valuation methods further distorted the results.

SEEA has been subject to several analytical and critical comments; a number of these were mentioned during the description of the system and its uses, and also in Chapter 1 Section 1.3 when discussing monetary valuation. Following the criticism, many controversial points were dropped or explained better in the ‘Operating Manual’. There are a few that still remain, and will probably result in some further resistance to introduce the SEEA at an official level. These

[52] Difference expressed in percentages of the NDP
[53] These technologies were not detailed in the report.
[54] The data is for 1997, but it was probably very similar in 1992, since the structure of electricity production does not change fast.

remaining points, which have not been mentioned so far, are presented below[55].

1. Scope and coverage of the accounts

(a) The SEEA does not include income accounts; a possible reason will be mentioned below at point 2(b).

(b) Environmental taxes are not shown explicitly, despite being key policy instruments.

(c) Physical accounts do not play an import role; monetary indicators seem to dominate policy issues. The result is that those resources that cannot be valued in monetary terms may end up in the background.

2. Monetary valuation. Calculation and application of adjusted macro-aggregates

(a) Soil degradation causes a fall in agricultural production. Accounting for soil degradation and subtracting the amount from GDP will constitute double counting.

(b) It is fundamentally incorrect to deduct imputed environmental costs from the GDP. If imputed hypothetical costs were real expenditures, production/consumption behaviour would change in a direction to reduce these costs. The result would be a completely different GDP (both volume and composition) on the one hand, and probably less environmental degradation on the other. Moreover, if environmental costs were paid, somebody would receive this amount and would spend it in some way, or even if the whole amount went into savings, it would change interest rates and investment behaviour. Either way, the economy and the GDP would look very different. Perhaps, to avoid this problem, the SEEA does not include income accounts as mentioned in point 1(a) above. Trade accounts and balances would also be affected. In addition, if environmental costs were really charged, it would have an effect on technological development, especially regarding technologies mitigating environmental damage. Several authors (van de Ven, 1999, Keuning, 2000, O'Connor, 2001) pointed out that the calculation of 'green GDP' is not an accounting exercise, but can only be achieved through modelling. In other words, calculating, what the *GDP would be* if all environmental standards were met. This is typically called 'greened GDP' as opposed to 'green GDP'.

(c) For those pollutants where avoidance/prevention or damage restoration is impossible at current technologies, maintenance valuation is not applicable. CO_2 is the most prominent example. The monetary valuation of such pollutants is, therefore, omitted. When maintenance costing gives an aggregate number with little practical meaning, the implementation of the SEEA has low priority. This may be the reason why no European country implemented the SEEA.

Section 3.3

[55] Some of the points are adapted from Harrison (1997).

National Accounting Matrix including Environmental Accounts

Development and present status of the NAMEA

The National Accounting Matrix including Environmental Accounts (NAMEA) is a *satellite system* to SNA; therefore it is based on the same international accounting principles. The first NAMEA was constructed in 1993 in the Netherlands. Since 1994 annual national accounts publications have been extended with the NAMEA. In the European Union the NAMEA or NAMEA-like approaches have been applied in recent years. Eurostat[56] has been overlooking projects in most EU member states, comparing methods and data sources, and will publish the results of national experiences (de Haan, 2000). NAMEAs are available in 13 member states of the EU as well as in Norway and Japan.

Concept and Structure

As opposed to the SEEA framework, NAMEA does not convert environmental data into monetary terms. NAMEA is a direct extension of the SNA with environmental data without modifying the core system; indicators derived from the SNA remain unchanged. Environmental accounts are denominated in physical units, which are most suitable to represent the aspect of the environment in question.

As the name tells us the NAMEA is a matrix, which is an extension of the regular National Accounting Matrix (NAM) with *two additional accounts for the environment*[57]. Matrix representation, in general, shows receipts in rows and outlays in columns. The structure of the original NAM is kept; the only difference is the disaggregating of the expenditure account regarding environmental related expenditure, and the inclusion of a separate tax account, where environmental taxes are shown separately. As for the environmental accounts, one account is for environmental substances, and the other is for environmental themes[58], that is major environmental problems. The substances account includes a large number of polluting substances and natural resources. In principle, the substances are directly connected to the industries that emit them. For example, CO_2 emission is connected to the electric power generating industry and not to the railway transport and manufacturers, which utilize electric power. The advantage of this approach is that different economic activities can be directly related to major environmental problems, and also keeps regular accounting simply implementable.

It is difficult to draw any conclusion from looking at a large number of pollutants,

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[56] The statistical office of the European Union

[57] This is the original version of the Dutch NAMEA. Country versions may differ, but most of them kept this structure in their pilot projects.

[58] In the case of the Netherlands, these are based on Netherlands' National Environmental Policy Plan 1993-96 (De Haan and Keuning, 1996)

therefore, the themes account is included, in which the substances are weighted and aggregated into categories of environmental issues, resulting in a few, easily understandable indicators. The environmental themes account covers two global environmental problems: global warming and ozone layer depletion, and four national problems: acidification, eutrophication, waste, change in natural resources. Some substances contribute to more than one theme, for example CFCs are included in both the global warming theme and the ozone layer depletion theme.

Applications of the NAMEA framework

In general, the direct connection between economic and environmental data makes it possible to use the NAMEA for analysing the linkages between the economy and the environment from several aspects. "Clearly, the physical accounts in the NAMEA might be suitable for transmitting this information to decision-makers as the physical accounts are integrated with the a National Account Matrix." (Ike, 1999, p.124)

✧ Indicators

One possibility to arrive at environmental indicators is the weighted aggregation of emission data, natural resources, etc. according to problem areas, as described above. The weights are based on the potential environmental threat (or another common feature) of substances. This method was applied, for example, in the Netherlands, Japan, and the UK. The number of environmental indicators is between 4 and 7, equal to the number of environmental themes in the country specific NAMEAs. The question, how these *theme-indicators* suggest sustainability, remains. One suggestion is to take the view that improvement in environmental indicators means a 'more sustainable development' then before. Although not directly related to the NAMEA framework, this approach is followed for example in the United Kingdom. 15 'headline indicators'[59] were developed, 7 of which are environmental indicators[60]. Theme-indicators in the NAMEA can be interpreted in a similar way.

Comparing theme indicators to target levels, thus arriving at new *'secondary indicators'*, is another option. In this case, the indicator would be the distance between the target level and the theme indicator (emission level). This way "for each type of emission (and sector), several levels may be stipulated and expressed as key ratios: ambitions, requirements, interim targets, ultimate targets, etc" (Hellsten et al, 1999, p. 60). Official policy targets, however, may give misleading results since they may be influenced by several factors other than sustainability. A scientific, long-term sustainability target is desirable. This sustainability level has only been determined for few environmental problems only. Hopefully, research in natural sciences will provide us with reliable targets in the future

Is it possible to derive at a single *environmental index* based on theme indicators? The

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[59] Altogether there are 150 indicators.

[60] " The government's aim is for all the headline indicators to *move in the right direction* over time…" (The British Government, 2001, p. 33, emphasis added).

relative contribution to total damage by each environmental theme is difficult to determine. We are left with a fair degree of subjectivity when choosing the weights if we wanted to construct a single environmental index. One possibility is to use the difference between the environmental indicator and the target level set by the environmental policy as weights. In the mid 90's in the Netherlands, year 2000 targets were considered for an environmental index calculation, but the idea was finally dropped due to objections to politically determined targets. Another option is to use the distance from the 'sustainability levels' as weights. The problem we encounter here is basically the same when trying to derive 'secondary indicators' from the theme indicators. As a result of these various difficulties, there is no single environmental index is calculated at present. Apart from conceptual questions, such an index would probably have little meaning regarding policy planning. Nevertheless, it could be called 'Environmental Development Index' (similarly to the Human Development Index) to indicate the some kind of average environmental quality in a country.

We can arrive at *eco-efficiency* indicators, which show the contribution of different industrial sectors to production, employment and environmental problems by presenting the relevant indicators together. A country with a strong manufacturing industry is likely to rely on natural resources, as well as cause substantial pollution and produce waste. This might result in policies that aim to reduce the output of these industries, which is a rational choice for alleviating the environmental burden within the country's borders. However, moving these industries abroad may not result in less environmental burden on a global scale, moreover, may even have reverse effects. Therefore, it is of primary importance to compare eco-efficiencies of industries between countries. NAMEA proves to be a very useful tool in this regard (de Haan, 1999).

✧ Direct and indirect contribution of industries to environmental problems

With the help of inter-industry input-output analysis the cumulative (indirect) emission of each industry can also be calculated. Imported input goods in the production process cause emission abroad, these can also be included. The assumption is that imported goods cause the same level of pollution as if they were produced in the country. Such calculations were made for example in the Netherlands, Sweden and Germany for several pollutants. It is obvious, that the pollution share of industries, which use inputs from heavily polluting industries, increases if measured accumulatively. In the Netherlands for example, the direct contribution of 'agriculture, hunting and forestry' to eutrophication is around 22 times higher than its contribution to GDP. This ratio falls to 14 if all intermediate inputs are taken into account. At the other end, we can find the 'food, beverages and tobacco industry' with the direct 'contribution to eutrophication / contribution to GDP' ratio being less than 1 (i.e. less than average). When accumulative emission is taken into account, this ratio jumps to 15. This tool can be further developed. In the Swedish analysis, production is broken down into 16 groups, but the national accounting system shows 110 categories. Goods at consumer level can be connected to their respective production with the help of I-O analysis. Thus, "following economic flows in the input-output system, it is possible to trace industrial emissions to categories of goods" (Hellsten et al, 1999, p. 61).

✧ Cross border pollution

The NAMEA differentiates pollution that result from domestic economic activities from those that originate in another country. A country's pollution balance can be derived from the system, similarly to its foreign trade balance. The Japanese NAMEA is special in this regard. It does not only distinguish domestic and foreign pollution sources, but gives detailed information on immediate neighbours: China, South Korea, North Korea and the rest of the world.

✧ Environmental expenditure

The NAMEA disintegrates the NAM from an environmental perspective, similarly to the SEEA. Cleansing services in the economy are separated from other services and divided into internal and external cleansing services. The production unit itself consumes internal services, whereas external services are sold to other production units or to consumers (including the government). Internal services were invisible before disintegration, and were not considered as output, whereas they are after disintegration. As a result, the total output increases, and so does intermediate consumption, thus leaving value added (GDP) unchanged. Consumption patterns can also be analysed with regard to the environment in a similar manner. Environmental consumer spending is separated from other spending in the disaggregated accounts. Any spending on equipment, such as water filters, kitchen waste disposal machines, etc. is shown separately in the accounts. It is difficult to separate such spending, because a consumption item may have several functions. Also, insufficient data puts a constraint on the implementation. Statistics in the current NAMEAs are the results of comprehensive surveys. Structural adjustments in the accounts at micro level may be necessary in the future to identify these items at the production stage already.

✧ Economic models and simulations

By using the NAMEA accounting framework, its database and indicators in macroeconomic modelling and simulations we can analyse causes and consequences of the present situation, and make predictions for the future, including the possible effects of different policy measures. The trade-off between the economy and the environmental goals become explicit; a common economic and environmental policy can be constructed; and the indicators can serve as a basis for discussion between policy makers and representatives of industries. For example, estimating the likely effects of an environmental tax on GDP, different sectors of production, employment, as well as on the environment.

The construction of a model for 'reverse' analysis is more complex (de Haan and Keuning, 2000). If we wanted to analyse the effect of emission constraints on the economy, a dynamic model is necessary that allows the inclusion technological development parameters and simultaneous changes in a number of other parameters – productivity, employment, investment, etc. Developing such models is in a very early stage; a fully workable model is not available yet.

A simulation for the Netherlands was implemented, in which economic affects of meeting the Dutch environmental standards were calculated, with the assumption of no technical change. With such an unrealistic assumption, this calculation resulted in huge necessary reductions in the economic activity. A similar calculation was done until the year 2030 but allowing for substitution between environmental, physical and human capital and also allowing for technological progress. The results show that growth in GDP can be sustained, though at a lower pace. These methods are not monetary valuations of emissions by maintenance costing, but through modelling, thus more realistically calculating how much it would cost close the 'sustainability gap'. In a different project, also in the Netherlands, NAMEA time-series analysis was used to identify links between consumption patterns and environmental pressures. In Sweden, the economic models based on the NAMEA were used to analyse the consequences of closing the Swedish nuclear power stations; to assess damage from sulphur depositions; to analyse the environmental implications of official growth forecasts; as well as to design environmental taxes (Hellsten et al, 1999).

✧ Monetary valuation

The NAMEA is specifically designed in a way to avoid the necessity of monetary valuation. In the Swedish project it is mentioned, however, that the database in the NAMEA can serve a basis for monetary valuation. "A net national product partly adjusted for environmental effects might be possible to calculate, even though a comprehensive adjustment is unrealistic." (Hellsten et al, 1999).

Directions of present research

The NAMEA framework is flexible and can be extended with additional environmental issues. The inclusion of several other environmental themes is being investigated at country level. NAMEA-Water accounts are prepared (or investigated) in several countries (the Netherlands, Austria, U.K.). These include the extraction of water as well as chemicals released into the water. Research is also being carried out to include the 'use of space', forestry and other natural resource accounts, harmful chemicals and biodiversity.

The NAMEA can be broken down to regional level and can be used for analysing local environmental problems and regional policy planning. This is being investigated in the U.K.

Currently NAMEAs are only available with a considerable time lag, for example, 2.5 years after the end of the accounting period in the Netherlands. Effort is being made to reduce this time lag to around 6-7 months.

Extensive efforts are being made to further extend the NAMEA to include social aspects. This is being carried out by the inclusion of another satellite account called the Social Accounting Matrix (SAM) and resulting in a so-called Social Accounting Matrix including Environmental Accounts (SAMEA) or System of Economic and Social Accounting Matrices and Extensions (SESAME). This project is already at very advanced stage in the Netherlands.

Despite promising preliminary results of country NAMEAs and positive international response, there is still a long way to go before such a system can become as standardized as the SNA. The avoidance of monetary valuation of the environment resulted in a system that has no controversial points; hence the NAMEA has received much less criticism concerning its principles than the SEEA.

Interestingly enough, the main criticism concerns the lack of monetary valuation. Bartelmus (1999) points out that if there is no aggregation of environmental impacts as costs, sectoral and national cost benefit analysis cannot be implemented. The same author argues that inter-theme comparison cannot be implemented, since the units are all different.

It is true, that 'ozone layer depletion equivalents' cannot be compared to 'acidification equivalents', but can we benefit from comparing different themes? These are quite different environmental problems, and comparing how much it would cost to avoid/prevent them (maintenance costing) does not tell us much. The SEEA 'Operating Manual' (UN, 2000) obviously mentions the same deficiency of the NAMEA approach. It also emphasizes that the NAMEA is only an intermediate stage during the implementation of the SEEA concept. Before the calculation of maintenance costs, the emissions data have to be allocated to the industries, which is exactly the same what the NAMEA does. The difference is that the NAMEA stops there, whereas the SEEA carries on and calculates the maintenance costs. Strictly speaking, this is true. But there are important differences that change the whole picture in the end. Firstly, the NAMEA stresses that environmental concerns can be addressed and analysed by looking at indicators that have direct relationship to emissions, and these can only be expressed in physical terms. Hence, the derived indicators from the two frameworks are fundamentally different. Secondly, one of the primary aims of the SEEA is to calculate EDP. For this, the calculation of imputed environmental costs is necessary. It is quite possible to calculate such costs for the economy as a whole, without allocating the emissions to industries. The NAMEA cannot skip the allocation to industries, because that is among its primary aims, and specifically constructed for that purpose. Finally, if we consider the NAMEA as an intermediate stage of the SEEA, then the next step (in the SEEA) is the monetary valuation of depletion and degradation. On the other hand, the NAMEA concept considers modelling and simulation to be next step, thus arriving at a 'greened GDP', as already mentioned. 'Green GDP' (EDP) and 'greened GDP' are fundamentally different concepts.

The NAMEA, however, in its current format inadequately handless the question of resources as inputs into the economic processes. Flows of exhaustible resources, by themselves, do not convey any meaningful message; reserves also have to be considered, or substitutes clearly presented. In the case of subsoil assets, monetary valuation makes sense even if market prices are distorted. Subsoil assets, of course, are already recorded in the SNA. A clear relationship between these flows in the NAMEA and the statistics in the SNA has to be established.

Section 3.4

Outline of the Japanese trial estimates for the SEEA and for the NAMEA

Japanese SEEA Trial Estimates

In the first phase of the project the years of 1985 and 1990 were targeted for the calculations. The experience gained from this first study served as a basis for the second phase, implemented by the Japan Research Institute, with more environmental items included, and the accuracy of estimation improved. Also, estimates were made for every fifth year from 1970 to 1995, thus a medium term time-series analysis became possible.

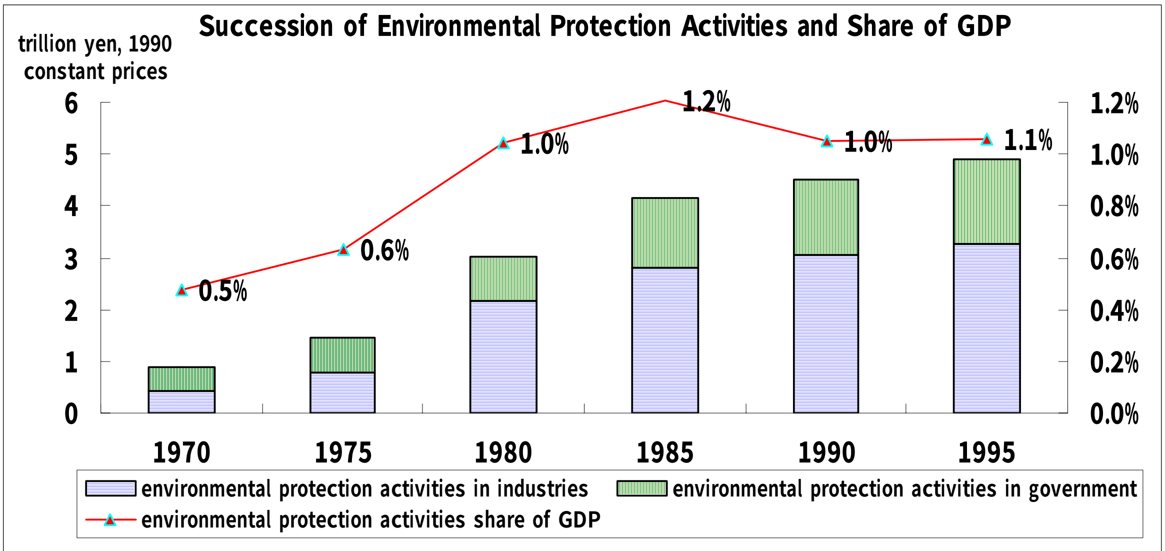
✧ Adjusted macroeconomic aggregates

In the period between 1970 and 1995 the imputed environmental costs decreased, thus the difference between GDP and EDP decreased from about 3% to 1%. Therefore, the growth rate of EDP exceeded the growth rate of GDP.

✧ Environmental Protection Activities

Activities of industries covered waste disposal, recycling and environmental assessment as external services, plus internal pollution control. As for the government, environmental administration, waste disposal and sewage treatment were included in the calculations. The share of private sector increased gradually from about 50% in 1970 to about two thirds in 1990. The total represented approximately 1% of the GDP. Chart 3.4-1 presents the changes of environmental protection activities.

Chart 3.4-1 Succession of Environmental Protection Activities and Share of GDP



Source: EPA: Outline of Trial Estimates for Japan's Integrated Environmental and Economic Accounting, 1998

✧ Assets related to environmental protection

These are those assets that are utilized during the environmental protection activities, including waste disposal facilities and pollution control facilities of the private sector; and sewage treatment and waste disposal facilities of the government. Stocks and accumulation were calculated for the accounting period. While the private sector shoulders two thirds of the environmental protection costs, it only owns less than 5% of the facilities to implement these activities, however. One reason is that those facilities of the private sector that are used in recycling are not included due to their multipurpose functions. Also, the government focuses on those environmental protection activities, where large investments are necessary in assets, but the value added is little. Finally, the government may not use its facilities as efficiently as the private sector, thus the productivity of its assets is lower.

✧ Environmental Assets

The estimates, in addition to man-made assets, covered timber and ‘others’ as *produced* (cultivated) assets; coal, limestone and zinc as *subsoil resources*; developed land, agricultural & wooded land and conservation regions in the *land* category. For all these assets monetary valuation was also implemented. In addition to the above, the assets also included air, water and soil, for which monetary valuation is not possible regarding the volume of stocks, only for changes in quality (degradation), for which the maintenance cost valuation was used. The distribution of the value of the total assets in Japan for 1990 (closing stocks) is summarized in Table 3.4-1. The table naturally includes only those items for which monetary valuation was possible regarding the stocks, as described above.

Man-made assets and developed land claim a share of almost 90% of the total asset value, included in the SNA already. In fact, so are the others, at least partly. The only assets that newly accounted for are part of wooded land and part of conservation regions[61].

Table 3.4-1

Value of assets in Japan for 1990 (constant prices, in billion yen)

Produced assets			Non-produced assets				
Man-made assets	Cultivated assets		Land			Subsoil resources	TOTAL
	Timber	Others	Developed land	Agricultural and wooded land	Conservation regions		
1,094,744	38,774	3,896	1,838,269	326,669	4,939	701	3,307,992
33.1%	1.17%	0.12%	55.6%	9.88%	0.149%	0.021%	100.0%

Source: Same as for Chart 3.4-1, original simplified by the author

Those assets that are directly connected to the ecosystem have only around 10% representation in Japan’s total wealth, most of which were already included in the SNA. Of course it can be argued that important natural assets, such as (non-cultivated) fish stocks were not

61 Those, which do not produce economic benefits to their owners, or do not have owners (i.e. non-economic assets by definition).

included, but that would hardly change the dominance of man-made assets and developed land.

Asset accounts should have an important role in an integrated accounting system. But as we saw above, monetary accounts show little of the natural wealth. Since SEEA should include physical accounts, we may put the monetary accounts aside and concentrate on the physical accounts. These physical asset accounts, however, seem to play no role when the results of SEEA estimates are presented. In the relevant papers surveyed (Economic Planning Agency of Japan, 1998; Oda et al, 1998; 深見正仁, 1998) neither were these physical accounts included, nor adequate reference made to them.

✧ Imputed environmental costs

Environmental issues in the Japanese SEEA originally targeted for monetary valuation:

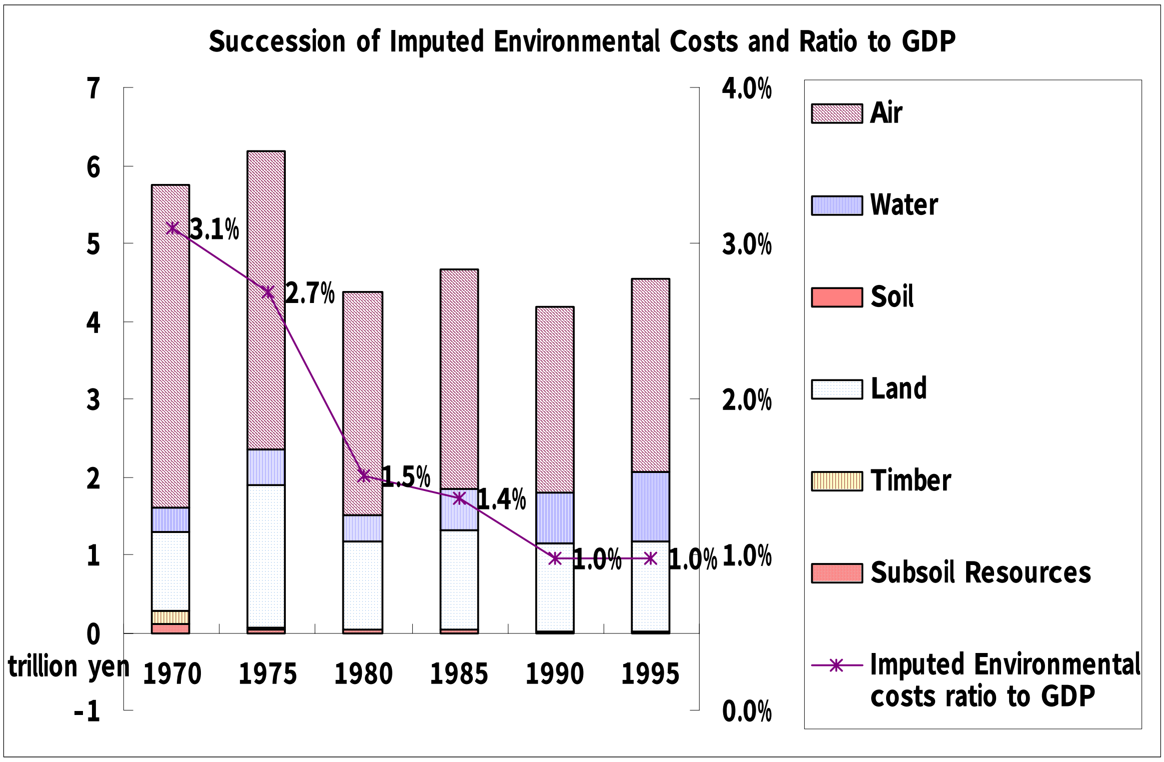
- Emissions: Air pollution (SO_x, NO_x), Water pollution (BOD, COD, N, P)
- Land development and deforestation
- Depletion of resources: coal, limestone, zinc
- Global issues: CO_2 emission
- Restoration of natural assets: polluted rivers, agricultural land

Losses due to *depletion* were calculated for land[62], timber and subsoil assets. The imputed costs for land and timber were the lost net profit due to abandoning deforestation or land development. In the case of subsoil assets, the ‘user cost method’ was applied. Imputed *degradation* (emission) costs were calculated by the maintenance cost method. Although initially planned, the monetary valuation of nitrogen (N) and phosphates (P) were dropped, because there were doubts if it is justifiable to impute values based on the national volumes[63]. Similarly, the monetary valuation of CO_2 emissions were also given up, since there is no way to avoid/prevent emission, neutralize CO_2, or calculate forgone profits if fossils fuels were not used. The results of these estimates are presented in chart 3.4-2.

Chart 3.4-2 The result of imputed environmental cost estimations

[62] Change of land use, i.e. land development.

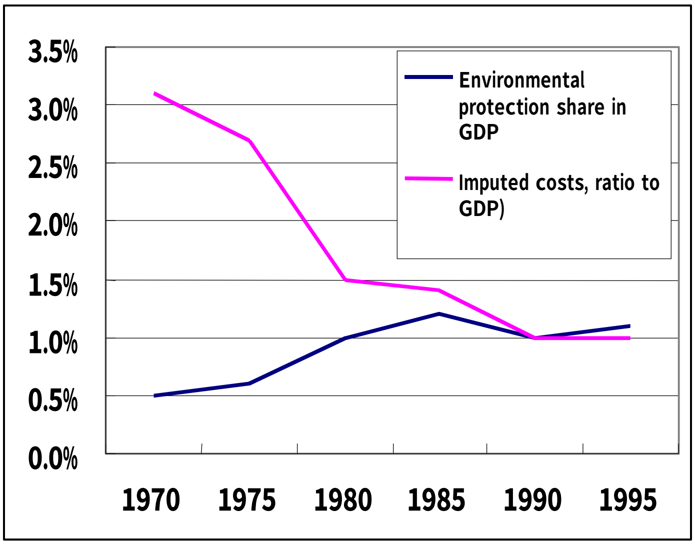
[63] Both substances cause eutrophication, which is a local problem. The substances were entered under water pollution in the SEEA, but they also cause soil pollution through the overuse of chemical fertilizers.



Source: Same as for Chart 3.4-1

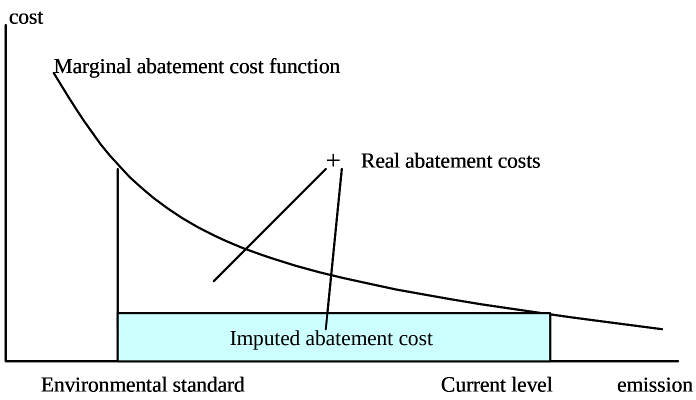
Imputed environmental costs were around 6 trillion yen annually in the 70's and decreased to around 4-4.5 trillion in the 80's and 90's.

Chart 3.4-3 Time-series of environmental expenditure and imputed environmental costs



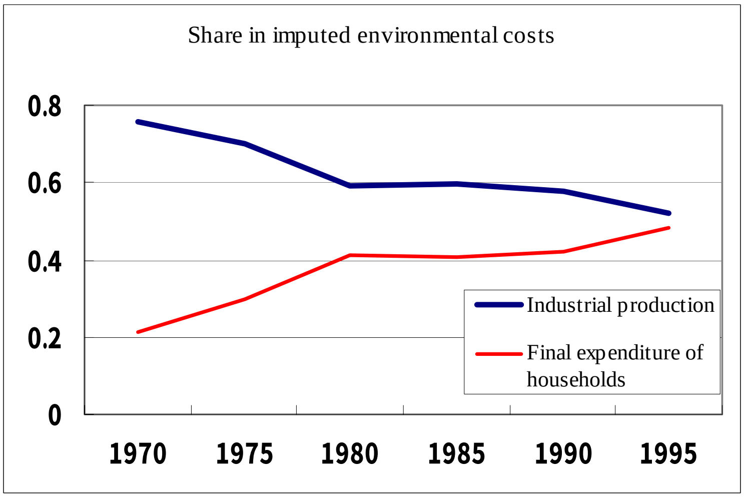
Since, GDP saw a large increase during this period, the ratio of these costs to GDP gradually decreased from over 3% to 1%. Comparing these amounts to the actual environmental protection expenditure (Chart 3.4-3) we can conclude that the more was spent on environmental protection, the less was the maintenance cost of depletion and degradation. We may say that things are heading in the right direction and the environment plays a more important in policy planning in Japan than earlier.

Chart 3.4-4 The calculation of imputed maintenance costs



There is some word of caution in place here, before we come to the conclusion that more than half of the environmental problems were eliminated because environmental expenditures were higher in 1995 than imputed costs. Firstly, very important items were not included in the imputed cost estimates. The exclusion of phosphates and nitrogen resulted in the fact that soil pollution (eutrophication) and groundwater pollutions have no share in imputed costs, moreover, the quality of soil slightly improved due to restoration work. This does not reflect the reality, since eutrophication is an important problem, even if emissions decreased in the last decade (see NAMEA below). CO_2 emission was not included in the estimates, either. Particulate matter from diesel engines, dioxin, nuclear waste, heavy metals, and depletion of fish stock were not targeted. Secondly, the imputed costs were calculated using marginal abatement costs: “cost per unit … the cost of reducing the residuals discharged by one unit” (EPA of Japan, 1998, p.7). As seen in Chart 3.4-4, these costs are likely to undervalue the costs of the real abatement process. “Empirical evidence … and theory both suggest that marginal abatement costs … are increasing in the level of emission reduction”(Hanley et al, 1997). Real abatement costs would be the whole area under MAC, whereas imputed costs are the shaded area only.

Chart 3.4-5 Industrial and household share in imputed costs

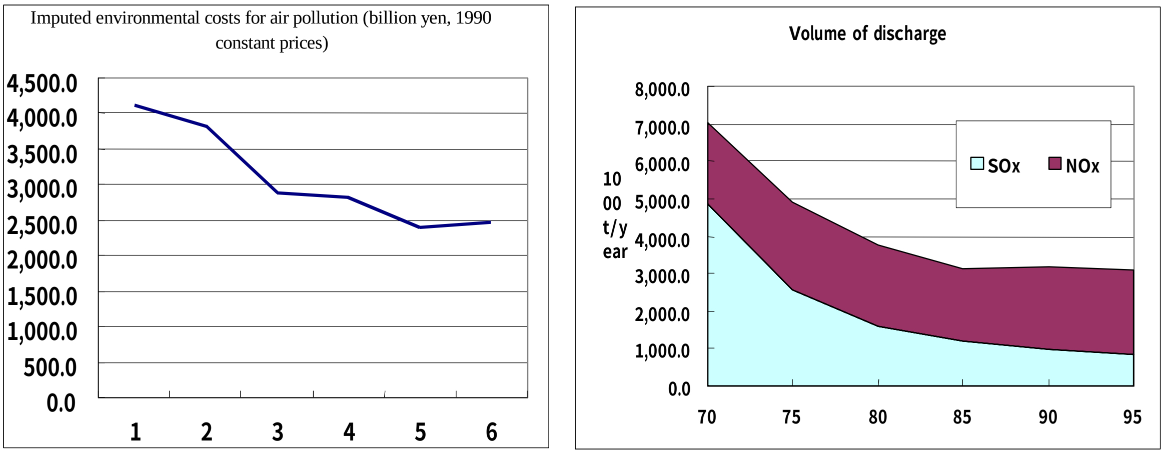


While the total amount of imputed environmental costs have not changed much in the last twenty years, there was a large shift of ‘responsibility’ from the industries to the households (Chart 3.4-5). In 1970 industries were responsible for almost 80% of the imputed environmental costs, by 1995, households and industries had almost an equal share.

✧ Physical and monetary time-series

Emission causing air pollution decreased (total of NO_x, and SO_x), and along with it the imputed costs decreased too (Charts 3.4-6 and 3.4-7). It is, however, important to point out that NO_x emission did not decrease at all, in fact, there was a slight increase in emission[64].

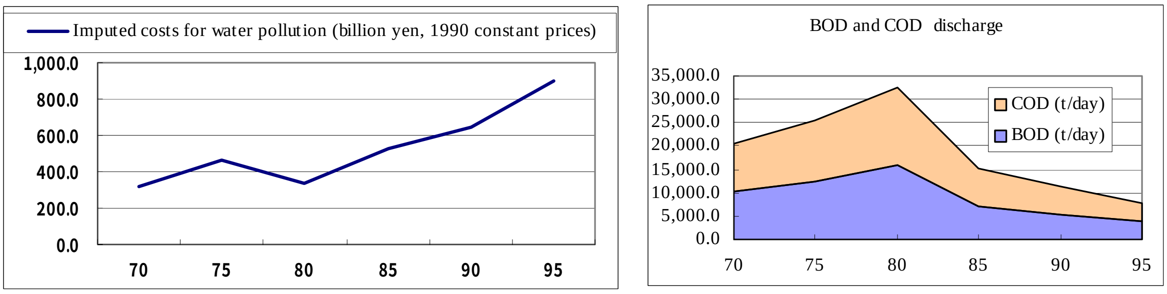
Charts 3.4-6 and 3.4-7 Comparison of emissions causing air pollution and their imputed costs



Data source: Economic Planning Agency of Japan, 1998; representation by the author

Regarding water pollution, however, no connection seems to be between actual emissions and imputed costs (Chart 3.4-8 and 3.4-9)[65]. While emissions increased until 1980 and there has been gradually decreasing since then, imputed costs show opposite trends. No explanation is found in the reports.

Charts 3.4-8 and 3.4-9 Comparison of pollutants causing water pollution and their imputed costs



Data source: Economic Planning Agency of Japan, 1998; representation by the author

The same emission-reducing technology for was 'applied' for the observed period to calculate the imputed costs. However, it may not be appropriate to use the technologies of the 90's

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[64] Imputed cost for air pollution was aggregated in the report, therefore the author could not show the imputed costs for NO_x and SO_x.

[65] The physical data shows daily emissions, while the costs are annual cost, but it there is no difference for the purpose of showing the trends.

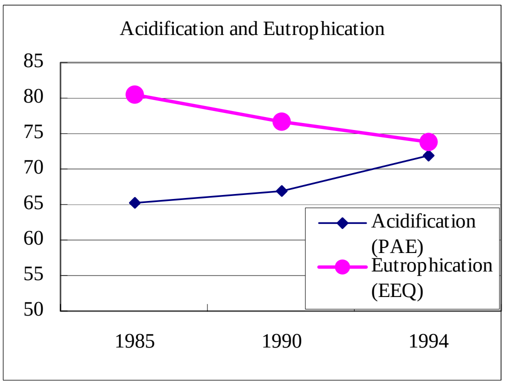
to calculate reduction costs of the 70's when these technologies were not available.

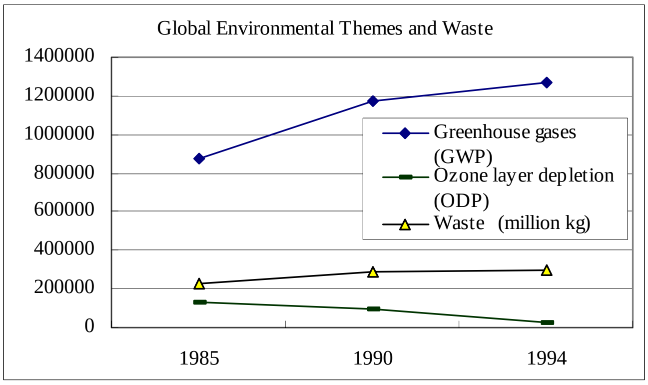
It is not clear from the reports how we should evaluate the results of this extensive research. Results are only listed as numbers and ratios. There are neither reflections on the past: why is Japan's integrated environmental-economic profile for the last 20 years is what we can see in the estimates, nor any implications regarding the future: what should the economic agents do, and who exactly should do it.

The Japanese NAMEA

The NAMEA project was implemented by Toshihiro Ike of the Economic Planning Agency of Japan. The Japanese NAMEA is generally based on the original Dutch NAMEA. The core NAMEA is only published for 1994, but detailed tables, which include economic and environmental indicators are available for 1985, 1990, 1994 (Ike, 1999). The data for 1994 are presented in the appendix. Charts 3.4 –10 and 3.4-11 show how the indicators changed over time. The lines higher in the charts do not represent more serious problems, because the units of measures are different. Such comparison of the environmental problems is impossible but also unnecessary.

Charts 3.4-10 and 3.4-11 Time-series of environmental indicators





Data source: Ike: A Japanese NAMEA, 1999; time-series graph representation by the author

While the emission of pollutants that cause eutrophication decreased about 10 %, there was a similar rise in the emission of pollutants causing acidification. Greenhouse gas emissions increased dramatically, and so did waste until 1990 and levelled off after that. The emission of ozone layer depleting substances dropped sharply.

These indicators can be expressed in relation to the GDP, per capita, by industries, etc. Choosing the 'agriculture, hunting, forestry and fishing' industry alone, we can see how it contributes to all environmental problems represented in the NAMEA.

Table 3.4-2 The contribution of 'Agriculture, hunting, forestry and fishing' to different indicators

Agriculture, hunting, forestry and fishing	GDP	Labour	Greenhouse gases	Acidification	Eutrophication	Waste
Share (%)	2.2	7.4	4.1	14	31	16

Data source: Ike: A Japanese NAMEA, 1999; data for 1994, calculations and representation by the author

Instead of looking at an industry, we can choose to look at a specific environmental problem, for example acidification. Including naturally occurring emission by volcanoes, and foreign sources of acidifying gases, we can have a clear picture where more effort has to be made to reduce acidification. Japan has the unfortunate situation that a third of the emission is from volcanic activities, but only 14% of acidifying gases are from foreign sources, compared to Sweden's 80%. It is clear that Sweden is better off doing more on the 'environmental diplomatic front' than making effort to reduce domestic emissions, while Japan can still reduce emission significantly by concentrating on domestic sources, which are responsible for 55% of emission.

The Japanese NAMEA has more details on the foreign sources of acidifying gases than other country NAMEAs. With respect to China, Korea and North-Korea, Japan is a net 'importer' of acidifying pollutants. On the other hand, Japan has a large 'pollution surplus' if the rest of the world (row) is taken into account (Table 3.4-3). Countries in Asia have high economic growth potentials, therefore, it is crucial to estimate the possible effects on the environment, including cross-boundary transmissions.

Table 3.4-4 Japan's pollution balance, regarding NO_x and SO_x

NO_x (million kg)	From	To	Balance
China	-147	8	-139
Korea	-89	16	-73
North-Korea	-13	3	-10
row	-5	759	754
			532

SO_x (million kg)	From	To	Balance
China	-380	36	-344
Korea	-98	45	-53
North-Korea	-25	11	-14
row	-4	1485	1481
			1070

Data source: Ike: A Japanese NAMEA, 1999

The weak points of the Japanese NAMEA are mostly those that were already mentioned regarding the NAMEA framework in general. In addition to those, the indirect pollution by industries is not calculated, though these would be very useful for policy making. There are few policy implications mentioned in the Japanese NAMEA that are specific to Japan, probably, because it was compiled by one person, whereas statistical offices implement these project in Europe.

Chapter 4

Conclusion and remaining issues

In Chapter 1, the concept and indicators of sustainable development were reviewed, and it was concluded that there is no single indicator at present that can clearly show whether we are on a sustainable path. Conflicting points regarding monetary valuation, the level of aggregation, flow/stock measures are not fully resolved. We will need a number of indicators to make sure that all dimensions of sustainable development are taken into account.

Research in the 1970's was concerned with welfare and its measurement, reviewed in Chapter 2. The MEW and the NNW, both calculated monetary values of environmental problems. The methods were different, and the one that has survived until today is the indirect valuation method applied in NNW.

Present concepts were reviewed in Chapter 3. Important conclusions can be best summarized by looking at the distance between an ideal integrated environmental and economic framework[66] and the emerging concepts of SEEA and NAMEA.

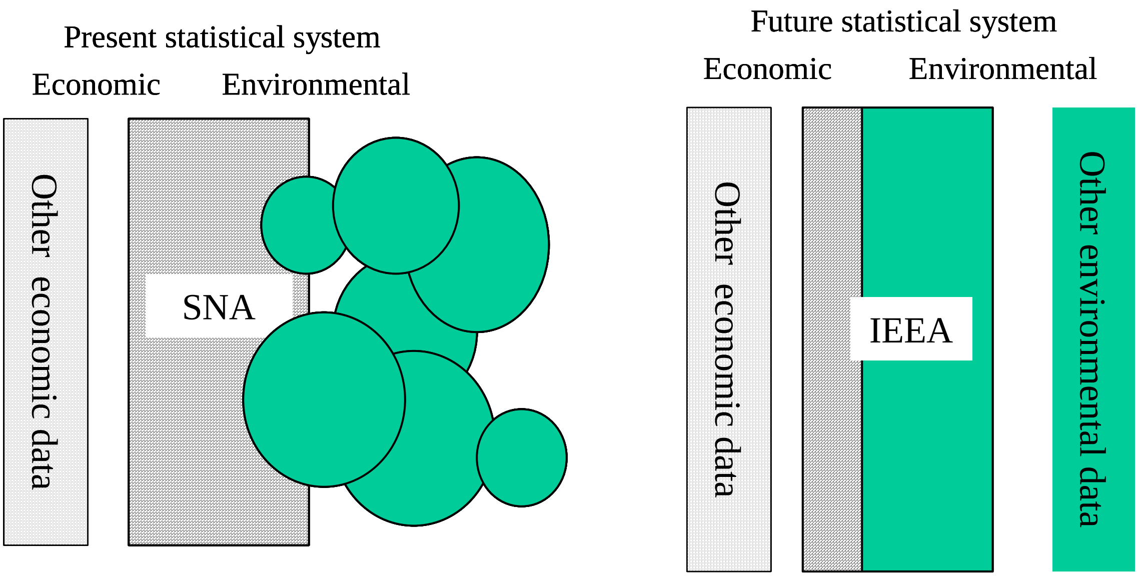
(1) Compatibility with the SNA, and the structure of the accounts

The NAMEA system is fully compatible with the SNA accounting rules, stock accounts are not included, however. With regard to the SEEA, there is an inconsistency between the expenditure and income accounts: nobody receives the imputed environmental costs that economic agents hypothetically pay.

Both NAMEA and SEEA trial projects pointed to the lack of well-structured environmental data. The current structure of economic and environmental statistics is pictured in Chart 4-1. Environmental data are organized by problem areas, geographical areas, but rarely by economic agents. While it is very important to keep the existing structure, organizing data in a format that is compatible with the SNA structure is a crucial step towards integration.

Chart 4-1

[66] The requirements of an ideal framework were discussed in Chapter 1, Section 1.1 last paragraph. The issues here are based on those criteria, but some points are aggregated to one here.



(2) Coverage of environmental problems

Both the SEEA and the NAMEA cover a large number of environmental issues already, and further extensions are being sought. Current NAMEA projects are investigating the inclusion of additional accounts, such as wastewater, use of space, etc. The flow representation of subsoil resources, however, gives no indication about sustainability.

In theory, the SEEA framework, in its current format, can accommodate most environmental issues. In practice, however, those problems for which monetary values cannot be imputed remain in the background or dropped from the beginning. Emphasizing monetary valuation may have a backslash on the original aim of the framework to incorporate a large number of issues.

(3) International issues

The NAMEA traces both cross border pollution and records these flows as 'pollution import/export', and also includes two global themes to account for global environmental stress caused by the country. Intermediate import products can also be included in these calculations. Indirect pollution calculations are implemented only in a few countries, however.

The SEEA accounting principles do not detail how direct pollution should be addressed. In the Korean SEEA, however, such analysis was implemented. Both the NAMEA and the SEEA can be improved on this front, but there are limits of how much a national accounting system can incorporate international issues.

(4) Policy-making and modelling

The NAMEA emphasizes the importance of modelling, but it is also clear that this is not the task of statisticians. They should provide an objective statistical framework that suitable for all sorts of modelling. These models are in their very early stage of development at present. The physical database in the SEEA could also be used for modelling, though no such exercise was implemented in the country estimates reviewed. Imputed monetary values are the result of computations themselves, and are prone to errors depending on the assumptions. Using these values as inputs in models may result in sizable errors. Instead of modelling, the SEEA adds imputed monetary values to each other and deducts the whole amount from NDP. This is rather peculiar in the light of modern economic theories. It is like saying that if the government increases spending, then the GDP will increase by the same amount. Deducting imputed environmental costs from GDP is ignoring the economic analysis of many decades.

(5) The provision of indicators

The environmental indicators we can derive from the NAMEA framework are objective, results of observations, with few estimations or assumptions. The indicators can be best interpreted if they are presented in time-series or compared to targets if they are available. The main indicators derived from the SEEA framework are the environmentally adjusted domestic product (EDP) and environmentally adjusted capital formation (ECF), both the result of computations. These computations can be complicated and change with time and it is doubtful if they have a place in an accounting system, which should be standardized. Most trial estimates showed a higher EDP growth rate than that of the GDP. Moreover, the difference between GDP and EDP values were only around 1-2% in most cases. It is difficult to avoid the thought: if our ‘green GDP’ is growing at a higher rate than GDP and the difference is minimal anyway, why do we need to talk about environmental issues at macro level in the first place? It is likely that the calculation of EDP is not adequate, or the concept itself is not appropriate for measuring what we want to measure.

(6) Monetary valuation

Adjusting GDP by the maintenance cost valuation could have a role at sectoral level or smaller environmental problems where ‘other things unchanged’ assumption can be made. At national level or for major problems an extensive and complex modelling exercise is necessary. The monetary valuation of resources may be useful, but it we should always keep in mind that the non-economic functions of non-renewable resources are ignored in the market price.

Issues for future research

One of the issues that have to be solved is the structural gap between economic and environmental data sets. GDP can be calculated by summing the value added of each industry, and theoretically it can be broken down to the level of firms. Ideally a similar system is desired on pollutants and resource use. Resource use can be addressed by energy/material flow accounts. Accounts on pollutants are in an immature state, however. In Japan many firms now do ‘green accounting’, advocated by the Ministry of the Environment (Ministry of Environment, 2001), and based on the International Standard Organization (ISO) guidelines. There are recently enacted laws, such as the ‘the PRTR law’[67], which oblige firms to report the release of certain chemical

[67] ‘Law Concerning Reporting, etc. of Releases to the Environment of Specific Chemical Substances and

substances and other pollutants. The link between the emerging micro-level integrated accounting and the macro-level integrated accounting has to be established.

Secondly, many environmental problems are country specific. Japan, for example, has few subsoil resources, thus inclusion of such resources may not be of primary concern. On the other hand, Japan is third largest nuclear energy producer in the world, and nuclear waste is something that needs to be monitored. There is a need to tailor the integrated accounting systems to national needs, international standardization may follow when there are enough country experiences.

Thirdly, the NAMEA or NAMEA-like systems are relatively advanced on accounting for pollution. The possible extension of the NAMEA to account for sustainable resource depletion has to be looked into.

Fourthly, it is important to outline the potential policy uses more specifically. Models that can make use of integrated accounting systems have to be developed together with the accounting system. If integrated policy relevancies are not identified clearly, and tools that can make use of the accounting system are not developed, the integrated accounting system will not be more than just recording environmental data in an SNA-like structure with limited use.

Finally, an integrated environmental and economic policy will have different effects on different social groups. There are experimental frameworks in the Netherlands to integrate the National Accounting Matrix (NAM), the NAMEA and the Social Accounting Matrix into one system, called System of Economic and Social Accounting Matrices and Extensions (SESAME). If the NAMEA gains ground in Japan, a similar system could be drawn up in the future.

Promoting Improvements in Their Management' enacted in 1999.

Some economic and environmental indicators of Japan

	Economic indicators			Environmental indicators								
	GDP (factor cost) (billion yen)	Labour volume (ten thousand)	Consumption expenditure (billion yen)	Greenhouse effects (GWP)				Ozone layer depletion (ODP)	Acidification		Eutrophication (EEQ)	Waste (million kg)
				All green-house gases	CO2	N2O,CH4	Fluoride		Emission (PAE)	Removed (RPAE)		
Household consumption			282354.3	175545	175545				1.3	-8.4	29.8	50536
Own transport				106755	106755				1.3	-8.4		0
Other				68790	68790				0	0	29.8	50536
Production	114349.3	2042.7		545503	417979	42468	85060	26455	48.9	-19.4	44.1	243963
Agriculture, hunting, forestry and fishing	9816.3	491.9		53300	32267	21033			20.8	-3.1	22.7	74949
Mining	979.5	8.6		5365	1821	3544			0.1	0		30793
Manufacturing	103553.5	1542.2		331682	322588	9094			27	-16.4		138221
Food	9528.7	181		8788	8788				3.8	-0.1		19233
Textile mill products	1885.5	70.1		7323	7323				1	-0.9		1636
Paper, paper products	3027.1	39.1		26958	26958				4.8	-0.8		24917
Chemical and allied products	8943.8	53.9		48590	48590				5	-1.9		19531
Ceramic, stone and clay products	3990.7	4.8		40089	40089				4.8	-1.3		19425
Iron and steel	7378.6	62.2		138208	138208				5.2	-7.1		30081
Non-ferrous metal and products		115.3		8110	8110				1.1	-0.5		3416
Fabricated metal products	6472.2	115.3		10084	10084				0.1	-0.7		3771
Miscellaneous manufacturing	62326.9	1015.8		34438	34438				1.2	-2.9		16211
Industrial process				155156	61303	8793	85060	26455	1.2	0	21.4	0
Energy transformation	12211.7	43.2		377562	369363	8199			14.4	-91.4		75422
Construction	49440.2	693.8		16386	16386	5940			0.2	-1		76931
Transport and storage	28225	366.5		133861	127921	9882			11.5	-6.5		1054
Environmental cleansing and sanitary		300.5		27028	17146				4.2	0		0
Other services	261326.1	3211.7		87399	87399				0.7	-2.2		8083
Change of land use and absorption into				-90834	-90834	94						
Imputed interest	-21371.8											
Rest of the world									21.3			
Natural phenomenon, volcano									45.1			
Total=column total 11	444180.8	6658.4	282354.3	1272450	1120905	66579	85060	26455	147.6	-128.9	73.8	455989
Destination												
Production (3)												
Crude petroleum and natural gas												
Environmental cleansing and sanitary												158566
Rest of the world, current (9)									75.7			
Global environmental themes (12)				1272450	1120905	66578.9	85060	26455				
National environmental themes (13)									71.9		73.8	297423
(Natural environmental theme, volcano)									10.6			
Total=row total 11	444180.5	6658.4	282354.3	1272450	1120905	66578.9	85060	26455	147.6	-128.9	73.8	455989

Source: Ike: A Japanese NAMEA, 1999; colouring added

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