PRODES

Promotion of Renewable Energy for Water

production through Desalination

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SCHEMES FOR SUBSIDIZING RENEWABLE ENERGY DRIVEN DESALINATION

WP6 – Task 6.3

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Outline

LIST OF ABBREVIATION

BW	brackish water
BWPV-RO	brackish water reverse osmosis with photovoltaic as energy source
ED	electrodyalisis
MVC	mechanical vapor compression
NSW	New South Wales (Australian state)
R&D	Research and development
RE	renewable energy
RE-D	renewable energy driven desalination
RES	renewable energy source
RO	reverse osmosis
RPS	renewable portfolio standard
SW	seawater
WGC	water generation cost

GLOSSARY

Adequate target rate	required rate of return; this rate is needed to calculate the water generation cost with the annuity method
Brackish water	water with a salinity of 1500 – 10000 ppm dissolved salt
Brine	the waste water that leaves the desalination plant
Feed water	the water that enters the desalination plant to be desalted.
Fresh water	up to 1500 ppm dissolved salt
Seawater	water with a salinity of 10000 – 45000 ppm dissolved salt

(see Cipollina et al., 2009, p.3)

EXECUTIVE SUMMARY

In this study support schemes for the desalination of water using renewable energy are proposed.

Water scarcity is a severe problem in many regions of the world today. One solution to this problem is desalination of salt water. However, conventional desalination plants are powered with fossil fuels and therefore generate environmental problems. The environmentally friendly alternative is renewable energy driven desalination (RE-desalination). But RE-desalination is more expensive than conventional desalination and therefore much less used. To promote RE-desalination and to help it enter the market, efficient support policies have to be developed and applied.

Technologies can be supported in three different stages. The research and development (R&D) stage, the demonstration stage and the market introduction and diffusion stage. In this study support schemes for technologies that are in the market introduction and diffusion stage are developed. The focus is on southern European countries.

By reviewing existing support policies for electricity, heat, desalination and RE-desalination, a number of problems have been identified that can harm the efficient implementation of support schemes. This leads to different requirements that should be met by a support scheme to be successfully established:

- To give security to the investors, the support scheme has to be a long term incentive. The investor should know in advance how much money he will get for what time period. To encourage this, long term targets should be defined for the share of RE-desalination in every target country.
- However, the aim of a support scheme is to introduce RE-desalination into the market, but not to support it forever. Therefore, the support should gradually decrease (degression) and end after a well defined time period.
- To make sure the amount of degression of the support is appropriate, the support scheme should be amended regularly to adapt it to the changing water generation cost of RE-desalination.
- To promote a wide range of different technological solutions, the amount of support should vary regarding technology, capacity and raw water quality.
- To benefit easily from the support scheme, investors should face as little administrative steps as possible. To this aim administrative and legal barriers should be removed.

- Only installations of new plants should be promoted, because the aim of the support scheme is to increase the installed capacity. Old plants should already be cost efficient.
- RE-desalination should not be over supported. The aim should be to install RE-desalination plants only in locations where no other solution like water saving or recycling is possible.

Independently from the support scheme chosen these recommendation should be included.

Additionally, it is important to implement framework conditions in the target countries, which help to promote RE-desalination effectively. Today, conventional desalination is subsidized. These subsidies have to be abolished. Fossil fueled desalination should not be supported with subsidies but on the contrary be taxed for its negative externalities. However, this will lead to an increase in water price and can lead to the problem that some consumers might not be able to pay for the amount of water they need for living. To avoid this, the water pricing system should be changed to a life line rate. With a life line rate the vital amount of water is cheap. The more water an individual or a family consumes, the more expensive becomes a unit of water. This has also the advantage to give an incentive for water saving.

Six support schemes to support RE-desalination are developed and discussed in this study:

- The first scheme is to promote RE-desalination with a production subsidy, which works as follows: For every m^3 of water a RE-desalination plant produces, the owner gets a fixed amount of money from the government. This money reduces the water cost for the investor and he can sell the water to a competitive price.
- The second scheme is to give an investment subsidy. With this subsidy the investor gets a share of his investment cost from the government.
- A feed in tariff for water is the third scheme. The government passes an act that obligates the water grid operator to buy the water from RE-desalination. Furthermore, the water grid operator has to pay the RE-desalination plant owner a bonus on top of the market price for every m^3 freshwater generated by RE-desalination.
- The fourth scheme is a quota scheme for water. The government fixes a certain share of the desalinated water that has to be produced by RE-desalination. Everybody who produces fresh water from RE-desalination gets certificates for his produced water. These certificates can be sold to operators of fossil fueled desalination. Every water supplier of fossil fueled desalination needs to produce the demanded share of RE-desalinated water or has to buy the equivalent in certificates.

- The fifth scheme is to implement an obligation. Every new desalination plant has to be powered with renewable energies. This is a special case of the quota scheme. The quota in this case is of 100%.
- The sixth option is based on the idea that to desalt water, RE-desalination first produces energy from renewable energy sources. These are already supported in many European countries. The energy production by RE-desalination plants could be included into the existing support schemes. Only minor changes in the policies would have to be made.

To evaluate these schemes to support RE-desalination, a benefit value analysis is made. This analysis leads to the conclusion that a feed in tariff for water is the best support scheme. The second and third best options are production subsidies and investment subsidies respectively. The result of a benefit value analysis is only an indicator and not a clear result, because the decision maker has to make subjective choices during the analysis. Therefore another decision maker might come to a different result. The decision makers of countries that want to implement a support scheme should repeat the analysis with their own preferences.

An improvement of the support could be achieved by a combination of support schemes. The feed in tariff has the disadvantage that it is not very well suited to support the simplest of all RE-desalination technologies: solar stills. Moreover, RE-desalination plants are extremely investment cost intensive, while the operation cost is relatively low, because renewable energy sources are for free. Especially individuals that are interested in small scale RE-desalination plants might not be able to bear the investment cost. To overcome these problems the feed in tariff could be combined with an investment subsidy. The investment subsidy also achieved a very good result in the value benefit analysis and can resolve the problems associated with a feed in tariff for water.

Another promising combination of support schemes could be an obligation combined with either a production or an investment subsidy. This combination has the advantage towards the combination feed-in tariff/investment subsidy that it assures that each newly installed desalination plant will be powered by renewable energy sources. It will therefore lead to a faster increase of the share of RE-desalination in the desalination market.

If a target country cannot, does not want to, or needs more time to implement a support scheme for RE-desalination, renewable energy driven desalination could at least be included in existing policies for energy to get some support without much effort for the policy makers.

This study suggests several possibilities to promote renewable energy driven desalination and demonstrates how to evaluate their potential for a given application. However, a general solution for every case cannot be given. Every target country should analyze which of the proposed schemes is most suitable in their specific case.

1. INTRODUCTION

The world water crisis is one of the largest public health issues of our time. One in eight people (884 million people) lack access to safe drinking water and almost 4,000 children die every day from the lack of clean and safe drinking water (see WaterAid, 2009, p.10). Today 2.8 billion people live in areas with water scarcity (see United Nations, 2008, p.40). As the world's population is growing, water scarcity will become an even larger problem in the future. An option to solve this problem and to preserve water resources is the use of desalination plants. Desalination is already needed and used in several countries like Spain, Australia and the United Arab Emirates. In 2009 the total installed desalination capacity of the world was of 59.9 million m^3/d. The desalination installations grew at a record rate in 2009 with 6.6 million m^3/d of new capacity installed. This shows the increasing demand for desalination. (see Global Water Intelligence, 2010, p.1) But desalination plants consume a lot of energy and therefore are, although they preserve water resources, not environmental friendly. A solution is renewable energy driven desalination. A considerable amount of research has already been performed on different RE-desalination technologies and some of these technologies are already in use. The company "RSD Solar water" for example installed its first renewable energy driven desalination plant, a solar still, in 1986 in Arguineguin, Gran Canaria. But RE-desalination did not get a mentionable market share until now. Different barriers have been found, explaining why this is the case. One of these barriers is the water generation cost. RE-desalination plants are still more expensive than conventional desalination plants. This paper develops and evaluates different support schemes for RE-desalination and suggests schemes with the potential to make RE-desalination technologies competitive and to help them gain an efficient market share in southern Europe. The focus is on market introduction and diffusion support schemes and not on the support of research and development (R&D) and demonstration projects. It is expected by the ProDes consortium that until 2016 new desalination plants with a total cost of $64 billion will be installed. The RE-desalination community is targeting a 3-5% share of that market, so RE-desalination will be worth $2 -3 billion in 7 years. (see ProDes, 2010, p.52) To achieve this goal, an efficient support scheme is needed. But policy makers have to be careful to not over support RE-desalination. Over support could lead to more desalination than is needed and put an unnecessary cost on society.

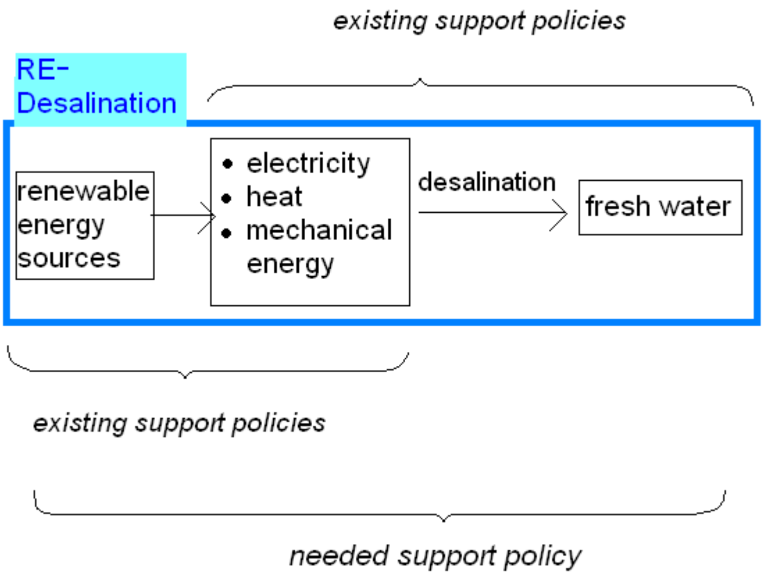

Figure 1: Overview about existing and needed policies

RE-desalination has two phases: First, electricity, heat or mechanical energy is produced using renewable energy sources. With this energy water is desalted. For both of these phases, the conversion from renewable energy sources (RES) into electricity and heat, and the desalination of water, well established support policies exist. However, to efficiently support RE-desalination and to increase its market share comprehensive support policies for the full RE-desalination process, adapted to different regions and social environments are needed as depicted in figure 1. Only few of these policies exist today and those which exist are only applicable to some of the existing RE-desalination technologies and capacities.

Chapter 2 of this study deals with the water generation costs (WGC) and the development stages of RE-desalination technologies. In Chapter 3 existing support policies for electricity, heat, desalinated water and water from RE-desalination are presented. In chapter 4 support policies for RE-desalination plants are proposed. These support schemes are evaluated in chapter 5 and a conclusion is given in chapter 6.

2. Costs and development stages of RE-D technologies

Before developing support schemes for RE-desalination it is important to know the water generation cost (WGC) of different RE-desalination technologies and to know in what development stage they are. This chapter illustrates that it is difficult to know the water generation cost and that a standardized method has to be developed, to make the WGC of different technologies comparable. Furthermore it shows that technologies need different support depending on the development stage they have.

2.1. Water generation cost

It is very difficult to find out the water generation cost (WGC) of different technologies. Standardized methods to calculate the WGC do not exist yet. Different companies make different assumptions, which leads to not always comparable WGC. The following factors contribute to an underestimation of the WGC. Often the water generation cost is calculated with 365 days of operation at full capacity. But a plant can only work with its full capacity, when the wind has the right force or the sun is providing a proper daily solar irradiation, etc. Moreover, during maintenance the plant might have to be shut down and cannot operate. The WGC are calculated with the annuity method. Depending on the chosen adequate target rate the water generation costs vary. They also vary depending on the stated operational lifespan. Mostly the operational lifespan is stated as 20 years. Most technologies have not been operated for 20 years, therefore it is not sure if this assumption is right. For the calculation of the WGC the installation, transportation cost and the cost for extra equipment are in most cases not included. Most desalination plants can desalt sea and brackish water. Their productivity mostly depends on the salinity of the feed water which may significantly influence the WGC. Based on the above stated arguments it can be assumed that the real water generation costs can be up to twice as high as the provided ones. A standardized method has to be developed, to make the WGC of different technologies comparable and to reflect the real WGC.

Even though the real WGC are difficult to know it is obvious that the cost vary depending on different technologies. Furthermore a trend can be seen when comparing the cost of one technology regarding the size and the water quality. According to the cost example in table 1 it can be seen that costs vary a lot depending on plant capacity and raw water salinity. This should be considered independently from the support scheme that is chosen. It is explained in more details in chapter 5.2.

Table 1: Capacity and water generation cost of PV-RO

(Cipollina et al., 2009, p.202, 206)

	Case study SWRO-PV	Case study SWRO-PV	Case study BWRO-PV
Capacity [m^3/d]	10	50	50
Energy consumption [kWh/m^3]	3.6	3.4	1.35
Investment Cost [€]	103,000	396,000	146,000
Water generation Cost [€/m^3]	5.68	3.87	2.09

2.2. Development stages

The different RE-desalination technologies are in very different development stages. Some are already well developed and are in the market introduction and diffusion stage, while other technologies are still in R&D stages or in the demonstration project stage. According to the development stages it can be differentiated between three types of support: Support for R&D, support for demonstration projects and support for market introduction and diffusion.

R&D has the aim to develop promising technologies that can benefit the society in the future. During Research and Development no money is gained by the scientists and their individual benefits are lower than their costs, whereas the benefit for society from the R&D activity is much higher than the social cost. To overcome this mismatch the state gives money to chosen research projects. The support is usually a subsidy of up to 100% of the R&D cost. (Garnaut climate change review, 2008, p.7)

The installation of the first demonstration project results in a lot of positive externalities in form of spillovers. The first company has to overcome barriers like regulatory and acceptance barriers. The next companies will benefit from their experience and better acceptance. Demonstration installations are therefore often supported with a subsidy of about 50%. (Garnaut climate change review, 2008, p.8)

After the R&D and the demonstration stage the technologies are reliable enough to enter the market, but they are still expensive, because economies of scale and learning curves could not work yet. The focus of this study lies on developing a support scheme for the market introduction and diffusion of RE-desalination technologies. How the market introduction and diffusion is supported in technology fields related to RE-desalination is explained in chapter 3. In Chapter 4 suggestions are made for how the support schemes could be used in the RE-desalination sector.

The different RE-desalination technologies have to be categorized into the development stages to decide which support is appropriate for which technology. In the Roadmap of the ProDes project different RE-desalination technologies have been arranged in a figure according to their capacities and development stages.

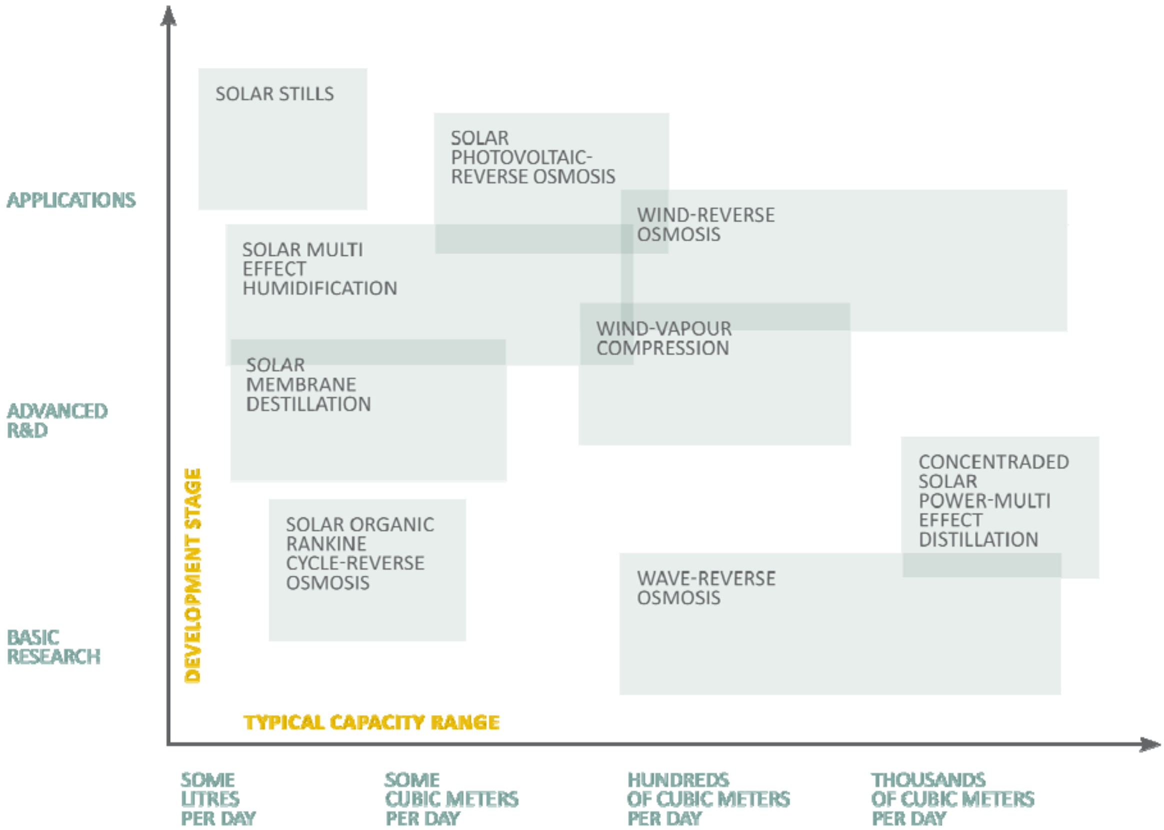

Figure 2: Development stage and capacity range of the main RE-desalination technologies

(ProDes RoadMap, 2010, p.37)

Based on figure 2, the technologies can be categorized as shown in table 2. Solar Stills, PV-RO and Wind-RO should be the technologies benefiting from the support scheme for market introduction and diffusion, whereas the other technologies need R&D and demonstration support.

Table 2: Development stages of the main RE-desalination technologies

R&D	Demonstration	Market introduction
• Wave-RO • Solar ORC-RO • Wind-VC	• Solar MD • Solar MEH • Solar MED	• Solar stills • PV-RO • Wind-RO

3. Existing support policies

Before developing a support policy for RE-desalination it is important to know what support policies already exist in other technology fields. The fields of electricity from RES, heat from RES and desalination are chosen. As RE-desalination is a combination of these technologies, it is probable that it can be promoted with a similar policy.

3.1. Support policies for electricity from renewable energies

Electricity generation with RES (RE electricity) is more expensive than electricity generation with fossil fuels (fossil electricity). Therefore it is difficult for RES to enter the electricity market, although there are much more environmental friendly than fossil fuels. To compensate this market failure, support schemes are implemented. The following chapters explain the most important renewable energy policies and give some examples of their successful implementation.

3.1.1. Feed-in tariff

The aim of the feed-in tariff is to pay the producers of electricity from RES a price high enough to cover their cost. This makes them competitive in the electricity market. This price is higher than the price producers of electricity from fossil fuels get.

Grid operators have to purchase the electricity from renewable energy sources (RES). The price they have to pay for this electricity is determined by the government. It is either a fixed price or a bonus paid on top of the electricity market price. Additionally a certain time period is fixed during which the grid operators have to buy the electricity and pay the fee. The price and the time period are important parameters for the producers to identify if their investment will be economical. The grid operator is allowed to hand on the extra costs from the support scheme to the end consumer by raising the electricity prices. This is an incentive for the end consumers to use less electricity.

Table 3: Advantages and disadvantages of feed-in tariffs

(Mendonça, 2007, p.13) (European Wind Energy association, 2005, p. 32)

Advantages	Disadvantages
• Good experiences have been made with this method at developing the renewable energy market. • Flexible in design through different tariffs for different technologies • Encourages small, medium and large scale producer • It is easy for investors to use the support scheme	• The policy is not close to the market. The price RE electricity producers get is independent from the market price • It is difficult to adjust the tariff to the production cost • It is difficult to achieve a target in from of a certain amount of renewable energy produced • If tariffs are not adjusted over time the tariff might be higher than needed and the costs for the consumers is too high

Example 1: Germany

The first feed-in policy in Germany was implemented in 1991 and was called Electricity Feed-in Act (Stromeinspeisegesetz). It mandated that grid operators pay 80% of the retail price as a feed-in tariff for electricity generated by RES. Furthermore, it obligated the grid operators to buy this electricity. But this obligation had a cap. The grid operator only had to pay the feed-in tariff until the share of electricity from RES reached 5%. This was to prevent very uneven burdens for regional grid operators. But the Electricity Feed-in Act had some problems. Wind turbines in northern Germany benefited most from the act and despite the cap northern grid operators had higher costs and therefore were less competitive. Moreover, the electricity prices fell due to the electricity market liberalization and caused the RES not to be profitable anymore.

Therefore in 2000 it was replaced by the Renewable Energy Act (Erneuerbare Energien Gesetz, EEG). Due to the problems encountered with the Electricity Feed-in Act, the feed-in tariff was no longer linked to the retail price, but fixed for 20 years. There was no cap for the amount of RE electricity produced anymore, but the feed-in reimbursement was distributed evenly among high voltage grid operators. Two other important changes were made: The degression of tariffs and the stepped nature of tariffs. The degression of tariffs means that new plants installed get less support than the plants installed in the previous year. For example a plant installed in 2003 gets a lower feed-in tariff than a plant installed in 2002 and so on. This is to keep the incentive for manufacturer to lower their production cost. It is derived from the learning curve and includes the fact that with the time production cost will decrease due to more efficient production steps and economies of scale. The stepped nature of tariff means that different technologies get different feed-in tariffs, because they do not have the same generation costs. Also different plant sizes get different feed-in tariffs. Another renewal was that the EEG has to be reviewed after 2 and then every 4 year to adjust it to new conditions. (see Ragwitz and Müller, 2005, p. 3-5)

The latest amendment of the EEG was made in 2009. Since then a feed-in tariff for self used electricity produced by PV on buildings is paid to the owner. If the PV owner uses the electricity produced himself he gets 25.01 cents/kWh. This new rule has been implemented to support self use of electricity and to relieve the grid. It furthermore increases energy efficiency by reducing transmission losses.

Example 2: Spain

The first feed-in law in Spain was introduced as early as 1980 and was called "Law for Energy Conservation" (*Ley 82/80 de Conservación de la Energía*). In 1997 it was replaced by the Electricity Power Act (*Ley 54/1997 del Sector Eléctrico Españo, jefatura de Estado, 1997*). Like the EEG the Power act obligates the grid owner to take the electricity produced by RES and to pay the producer a feed-in tariff. The producer can choose between two options: getting a fixed price or getting a premium on top of the variable market price. The producer decides every year which option he wants to use for the next year. (see Ragwitz and Müller, 2005, p.8) Furthermore, the increased remuneration is guaranteed for 10 to 25 years, which leads to security for the renewable electricity producer. The degression of feed-in tariff in Spain is not fixed from the beginning but is determined every year to follow the market trend.

The Power act was amended several times for example by the RD 2818/1998, the RD 436/2004 and the RD 661/2007. Moreover, the tariffs for solar photovoltaic are reviewed every quarter of a year and every other tariff every year. All these reviews lead to a well adjusted policy.

The highest feed-in tariff a RES can get in Spain if it is installed now, is 34€cents/kWh for photovoltaic. (BMU, 2008)

3.1.2. Quota scheme

The method of the quota scheme is that the government fixes a certain amount or share of renewable electricity that has to be produced until a fixed date. Electricity producers are obligated to provide a certain percentage or fixed amount of RE electricity. Once the quantity is defined, a certificate market is established. Everyone who produces RE electricity gets an amount of certificates corresponding to the amount of RE electricity produced. Now the certificates can be traded. Producer of RE electricity can sell their electricity plus their certificates and therefore earn more than without the quota scheme and become competitive. Producers of electricity produced with fossil fuels have to buy the certificates to fulfill the target and therefore internalize their externalities like CO_2 emissions. The advantage of the quota scheme is that the RE electricity that is the cheapest for society is produced first. But this can also be seen as disadvantage, because the aim of a support scheme should be to promote every promising technology and it is not known today which technology will be the cheapest in the future. To promote every promising technology, factors can be introduced. If for example the cost for electricity from PV is ten times higher than the cost for electricity from wind, wind would get the factor one and PV the factor ten. In this case wind energy would get one certificate per MWh produced while electricity from PV gets ten certificates. (see European Wind Energy association, 2005, p.37)

Table 4: Advantages and disadvantages of quota schemes

(see European Wind Energy association, 2005, p.36) (see Mendonça, 2007, p.14)

Advantages	Disadvantages
• It is easy to achieve a target • The price for the certificates is adapted automatically to the production cost	• Little experience (In experience it is in most cases not working effectively) • A certificate market has to be created →more complex scheme than the others →more difficult to implement • Difficult to find the right quota • Promotes large plants. Not suitable for small plants with private owners • No incentive when the quota is achieved • No long term security for investors (price of the certificates varies) → higher risk → higher costs

Example: Texas

The quota scheme in Texas is called Renewable Portfolio Standard (RPS). The capacity targets of the Texas RPS are 850 MW of new renewable electricity by 2005, 1400 MW by 2007, 2000 MW by 2009 and 5880 MW by 2015. All electricity retailers in the competitive market share the obligation. They have to fulfill a part of the target proportionally to their electricity sale. Electricity retailers get the certificates for every MWh. Certificates are tracked over a web based certificates tracking system. The penalty of not fulfilling the target is the lesser of 5US¢ or 200% of mean renewable energy certificates for each missing kWh.

Western Texas, where annual wind speeds of 8m/s are common, is a very good location for wind turbines. With this plus the federal production tax credit (PTC) of 1.7US¢/kWh wind power projects in Texas are able to deliver power to the grid for less than 3US¢/kWh. From the RSP wind energy has mainly benefited. To also encourage other energy forms, in 2005 the target has been set to produce 500MW of renewable energy capacity of non wind resources.

Some people say the target for Texas was not ambitious enough. In fact the target for 2009 was reached 4 years early in 2005 and the target for 2015 was reached in 2008. Setting the goals too low has had negative consequences. The certificate price for example collapsed as more capacity was built than mandated. (Gülen at al., 2009, p.8, 9)

Example: Italy

Italy has had a quota scheme since 2002. It is called Certificati Verdi. One particularity of the Italian system is that different technologies get different amounts of certificates for the same amount of electricity produced. Wind offshore turbines for example get 1.5 certificates per MWh produced while geothermic plants get 0.9 certificates per MWh. (see Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit, 2007)

3.1.3. Production subsidy

In this paper, a subsidy is defined as a direct payment towards a plant operator from the government. A government can influence the price of electricity produced from RES by giving production subsidies. For every kWh_{el} that is produced from RES, the producer gets a fixed amount of money. The electricity can now be produced cheaper and the costs are lower than or equal to the market price.

Table 5: Advantages and disadvantages of production subsidies

Advantages	Disadvantages
• Very simple support scheme • Easy to comprehend for the investor • Flexible, can be diversified regarding technology and capacity • supports efficient plants	• It can get very expensive for the government if they have to support a large number of RES

Example

In 1989 the German “100MW-Wind-Program” started. In 1991 it was extended to the “250MW-Wind-Program”. Operators of wind turbines could choose between an investment subsidy of 102 €/kW and a production subsidy of 0,041€/kWh for a period of 10 years. In

1991 the Electricity Feed-in Act was introduced and wind turbines received a feed-in tariff for the electricity fed into the grid and the production subsidy was reduced to 0,031 €/kWh. The last subsidies were approved in 1996 and the program ended in 2006 when the last production subsidy was paid. (see Langniss, 2006, p.1)

3.1.4. Tax incentive

A tax incentive leads to a reduction of taxes that an investor has to pay. It can be applied to investments and is then called investment tax incentive or it can be given on a product produced and is then called production tax incentive. Furthermore, a tax incentive can be a tax credit or a tax deduction. A tax credit is treated like a payment already made toward taxes owed, in contrast to a tax deduction which reduces taxable income. (see Energy Information Administration, 2008, p.12) A tax incentive for renewable energies reduces the tax that the producer has to pay and therefore lowers his prices. A tax incentive has a similar impact on budgets as a production and investment subsidy.

An objection to the investment tax incentive is that it supports capacity installation and not production. It can therefore lead to expensive but ineffective plants. During the 1980s in California some wind turbines were build in unprofitable locations to get the investment tax incentives. This problem can be avoided by using production tax incentives. (Clement at al., 2005, p.7)Tax incentives have less impact on the development of renewable energies than other policies like feed-in tariffs or quota schemes. But due to their flexibility they often escort other policies like in Texas the RPS (see 3.1.2).

Table 6: Advantages and disadvantages of tax credits

Advantages	Disadvantages
• Flexible → different technologies and capacities can be promoted	• Less incentive than feed-in tariff or quota scheme (Clement at al., 2005, p.6) • Same effect as subsidies, but cannot fully be used if ones tax liability is less than the credit • More difficult to understand for the investor than subsidies
Production tax incentive	
• Promotes efficient plants	
Investment tax incentive	
	• Does not promote efficient plants

Example: production tax credit

The US government gives production tax credits (PTC) for wind energy. Qualified applicants are taxpayers from large utility scale wind projects. In 2008 the PTC was of 2USc/kWh and was guaranteed for the first 10 years of the wind turbines operation. The PTC is adjusted annually for inflation. Unfortunately this PTC is not a long term incentive regarding future installations. It expires and has to be renewed. In 7 years it expired 3 times and later had to be renewed. This uncertainty resulted in a decrease of wind turbine installation just before the PTC expired and a boom when it was renewed. The American Wind Energy Association (AWEA) advises that only a long term tax incentive can stabilize the wind turbine installation. (see State energy conservation office, 2009)

3.2. Support policies for heat from renewable energies

In Germany there are two policies that support heat generated by RES with the target to cover 14% of the heat production from RES by 2020: The market incentive program (Marktanreizprogramm (MAP)) and the renewable energy policy for heat (EEWärmeG).

3.2.1. Investment subsidy

An investment subsidy is a partial payment that is granted to an investor for the installation of a capacity. It is a fixed amount of money based on the capacity to be installed or a percentage of the eligible investment cost. An investment subsidy for renewable energy investments results in less investment costs for the investor and the electricity can be sold at a cheaper price. The disadvantage is that an investment subsidy promotes the installation of large capacities but not of efficient plants. However, investment subsidies can be combined with other policies such as a feed-in tariff.

Table 7: Advantages and disadvantages of investment subsidies
(see European Wind Energy association, 2005, p.36)

Advantages	Disadvantages
• Very simple support scheme • Easy to comprehend for the investor • Flexible, can be diversified regarding technology and capacity	• does not support efficiency of plants • It can get very expensive for the government if it has to support a large number of RES

Example

The MAP exists since 2000. It supports the installation of renewable heat systems. If o renewable heat systems is installed, the owner can get a basic support. If additionally he fulfills other conditions he can also get a bonus support. For example for a solar thermal plant smaller or equal to 40m² the owner gets 60€/m² basis support, but at least 410€. If the warm water is not only used as warm fresh water but also for heating, the support raises to 105€/m². (see Solarserver, 2009)

In the year 2001 the support was cut surprisingly, because of short budget funds. The solar collector market experienced a decrease of the demand of 40%. In 2005 the collector market had still not recovered from this demand decrease. This shows that long term incentives are needed, on which the industry can rely. (see Nast et al., 2005, p.133)

3.2.2. Obligation

The EEWärmeG became effective on January 1st, 2009. It obligates owners of buildings that are constructed after January 1st 2009 to cover part of their heat consumption with RES. Every kind of renewable energy is possible, but also other climate protecting action can be taken instead of using renewable energies like extra heat insulation, using heat from a district heating grid or from combined heat and power (CHP). Of course such a policy can only work if there is a penalty for not applying it. A fine up to 5,000€ or up to 20,000€ can be given, depending on the offence. (see Wustlich et al., 2008, p.9, 10)

To compensate the negative effects of the EEWärmeG, especially the fact that the obligation leads to much higher construction costs for buildings, the market incentive program MAP gets more money. Since 2009 every year 500 million € will be available for the program.

Table 8: Advantages and disadvantages of obligations

Advantages	Disadvantages
• Every house will be partly heated with renewable energies	• Even if it is very expensive for the house builder the investment has to be made

3.3. Support policies for water from desalination

In some regions desalination is needed to secure the water supply for a population. But fresh water from desalination is more expensive than fresh water from natural sources. So that the population does not have to bear this extra cost some governments subsidize water.

3.3.1. Investment subsidy

California gives subsidies in the amount of US$50 million for projects of desalination of sea or brackish water. Eligible are projects that get at least 50% of the total cost from non state source. The subsidy is capped at US$5million per project. “Eligible projects shall be selected based on demonstrated need for new or alternative water supplies, project readiness, and degree to which the project avoids or mitigates adverse environmental impacts.“ (California Water Code, 2002, SECTION 79545-79547.2) Projects have better chances to be selected if they incorporate ecosystem restoration and water quality benefits.

3.4. Support policies for water from RE-desalination

Support schemes for RE-desalination only exist in few countries. This chapter explains the policies that exist in Australia and on the Canary Islands.

3.4.1. Governmental decision

In Australia several desalination plants in construction will be powered by RES. One example is the desalination plant in Kurnell, which will be powered by renewable energy produced at a wind farm in Bungendore in New South Wales (NSW). The construction for this plant started in 2007. (see Costa, 2009, p.1) It will be a reverse osmosis desalination plant and will provide up to 15% of Sydney’s water supply at the beginning of 2010. (see Sydney water, 2009)

Renewable energy policies in Australia have been introduced by the state rather than by the federal government. (New South Wales government, 2006, p.3) There is no regulation regarding desalination and renewable energies, but as desalination plants need a huge amount of energy, most state governments have chosen to power them by RES to achieve their renewable energy targets. The desalination plants and RES in Australia are not necessarily directly linked, but there is rather a contractual relationship whereby renewable generators will feed in enough renewable energy to compensate the demand from the desalination plants. (R. Belt, personal communication, 14.9.2009) The disadvantage of this system is that only large systems will be promoted by the government.

Table 9: Advantages and disadvantages of governmental decisions for RE-desalination in Australia

Advantages	Disadvantages
• Big RE-desalination capacities can be built	• Only for large plants • A private person cannot participate in this program • Not for remote areas

3.4.2. Investment subsidy

The Australian Government has a “national urban water and desalination plan”. It aims to secure the water supply for Australia’s major cities. “The objective of the plan is to support major desalination, water recycling and storm water harvesting projects that contribute significantly to achieving the aim of improving security of water supplies to Australia’s cities, without adding to greenhouse emissions” (Australian Government, 2008, p.3). The financial assistance for each project is up to 10% of the eligible costs or up to AU$100 million, depending on which is lowest. (see Australian Government, 2008, p.3, 4)

To be eligible for approval under the plan a project has to:

- use desalination, and/or recycling and/or storm water harvesting to contribute to the water security,
- have a capital cost of at least AU$30 million and
- cover 100% of its energy needs from renewable sources or fully offset the carbon impact of the project’s operations.

A 100 Mm^3/year desalination plant will be built in Adelaide to reduce South Australia’s reliance on the Murray River. This project will be supported with AU$100 million from the national urban water and desalination plan. (see Wong, 2009).

3.4.3. Special regulation

There is a Canary Islands initiative focused on promoting the joint implementation of wind farms and RO desalination (see 2.5.3) in the same facility, but with both systems connected to the general grid (not a stand-alone wind RO system, where the wind energy is directly used to power the desalination plant). On the Canary Islands the number of installations of wind turbines allowed is limited due to the reduced size of the electric grids. It is much smaller than the grid of Spain, which is connected to Europe and Africa. As wind power has fluctuations and interruptions, the stability of insular grids requires a restriction of the total wind power connected. Until 2015 on all Canary Islands together it is limited to 440 MW, according to the official energy plans (Canary Islands Official Bulletin, 4 of May 2007). This power has already been awarded by a public tender. However, when a wind installation is combined with a load, like a desalination plant, the owner does not have to follow the same procedure like other installers of wind farm. In this case, wind power can be installed up to two times the power consumption of the load, but the annual energy consumption of the load has to be at least 50 % of the energy produced by the wind farm. Therefore, the combination of wind energy with desalination plants has advantages for investors on the Canary Islands. A public tender for wind turbines in combination with loads was launched, with a total power of 45 MW. It has been partially awarded. (Canary Islands Official Bulletin, 22 of May 2007) (V. Subiela, personal communication, 15.12.2009)

Table 10: Advantages and disadvantages of special regulations

Advantages	Disadvantages
• no extra cost for the state • does not influence the water price	• weak incentive • no cost reduction for RE-desalination plants

4. Development of support policies for RE-desalination

Based on chapter 3 different support schemes for RE-desalination are developed in this chapter. But before a support scheme can be implemented good framework conditions should be created in target countries. A new pricing system should be implemented in all countries to make water available for everyone but still encourage water saving.

4.1. Water pricing system and water subsidies

The EU Directive “Water Framework Directive” from 2000 requires that all EU states should have water prices that reflect the real water generation cost until 2010 to give an incentive to reduce the water consumption. This will raise the water prices and RE-desalination will need less support. To reflect the real cost of water, existing support for fresh water should gradually be abolished. This stands in contrast to the aim of this paper to have support scheme for RE-desalination. But the aim of a support schemes for water is not to reduce the water price but to introduce new technologies. Furthermore, not every support scheme reduces the price of water but in contrast raises it.

Water is a scarce and a vital good. Everyone should be able to afford the vital amount of water. To achieve this and at the same time comply with the Water Framework Directive a new water pricing system is needed. The aim of this system is to:

- make the vital amount of water available to everyone,
- but at the same time encourage water saving and
- reflect the water costs as good as possible.

A good approach for that is a life line rate. (see Cone and Hayes, 1980, p. 206) With this pricing system the first necessary unit of water is cheap. The price of the following water units increases in blocks. Furthermore, the connection fee should be abolished or at least be very low because it has a higher percentage impact on the water bill of low consumers, usually poor people than on the water bill of high consumers who are generally richer. To introduce such a pricing system, metering is important. Water meters that are able to meter different price levels should be installed, without putting too much cost on the consumers. Studies have to be made to find out the vital amount of water that industry, agriculture and private persons need and the price they are able to pay. With this knowledge a fair water prices system can be created.

4.2. DEVELOPMENT OF SUPPORT POLICIES FOR RE-DESALINATION

Several different support schemes for renewable electricity, heat and water have been introduced in chapter 3. Based on these findings different support schemes for RE-desalination are developed in this chapter. The aim of the study is to get an overview of the possibilities that exist to support RE-desalination. To implement a support scheme in a target country, a detailed market study has to be made. This study focuses on general suggestions for support schemes. It has to be adapted to every country individually. To give an idea of how the support scheme could work and what amount of support is needed an example has been created. It is very hard to find data to calculate the amount of support that would be needed with the different support schemes. The data taken are developed with different assumptions (see Annex I). The same data are taken for every example. Moreover, recommendations are made that should be considered while implementing a new support scheme. In the developed support schemes it is assumed that these recommendations are implemented.

4.2.1. RECOMMENDATION FOR AN EFFECTIVE IMPLEMENTATION OF A SUPPORT POLICY

The experience with support schemes in the field of electricity and heat from renewable energy sources, desalination and RE-desalination, has shown that support policies can be implemented in an effective and in an ineffective way. To make sure a policy will be effective the following requirements should be met:

- Investor security through policy stability

Only if a support scheme is a long term incentive it can lead to a huge increase of RE-desalination. A support scheme can be a long term incentive in terms of the duration of the support for one plant and regarding future installations. A well implemented support scheme should fulfill both qualities. A long term incentive in terms of the duration of the support for one plant means that if a plant is installed today it has the guarantee to get the support for a defined period of time. The German feed-in tariff, for example, is very successful because investors are guaranteed to receive the feed-in tariff for 20 years. The investors can predict easily the benefits from their investments which makes the investment low risk and therefore attractive. A long term incentive regarding future installations means that the policy will still be effective in several years and support the installation of plant is the future. The PTC in Texas is not a long term incentive regarding future installations. It expires and has to be renewed frequently. In 7 years it expired 3 times and later had to be renewed. This uncertainty resulted in a decrease of wind turbine installation just before the PTC expired and a boom when it was renewed. The American Wind Energy Association (AWEA) advises that only a long term tax incentive can stabilize the wind turbine installations. (State energy conservation office, 2009) A similar case occurred in Germany with the MAP, an investment subsidy for investments in renewable heat systems. In the year 2001 the MAP has been cut surprisingly, because of short budget funds. The solar collector market experienced a decrease of the demand of 40%. In 2005 the collector market was still not recovered from this decrease in demand. This shows that long term incentives are needed, to offer security to whole branches.

- Long term, sufficiently ambitious but realistic targets

Each country should have a concrete target of how much RE-desalination should be installed in which time frame. Such a target helps to determine how high the incentive should be and to control the success of the support scheme. Furthermore, it encourages the creation of a long term incentive regarding future installations.

- Degression and defined end of the support

The aim of a support scheme is to help a technology to become competitive and not to support it forever. Therefore the goal should be set from the beginning on to reduce the support until no support is needed for the technology anymore (UNEP, 2004, p.7). The support scheme should be a long term incentive but still end sometime in the future. The cost of RE-desalination will go down in the future due to R&D, economies of scale and learning curves. Moreover, the price of water will rise in the future, making it easier for RE-desalination to become competitive.

- Differentiation between technologies, capacity and raw water quality

In a support scheme for market introduction it should be differentiated between technologies, capacities and raw water quality. The differentiation can be made through the amount of support in € and the degression. Technologies that are in the market introduction phase can differ in development stages. Technologies that are in a lower development stage should get relatively more support, but with a higher degression than technologies with a high development stage. Plants with high capacities can produce water at relatively low costs compared to plants with low capacities, because of economies of scale. But small autonomous systems have their markets in remote areas, where the water prices are higher than in well accessible areas. The support should therefore be adapted to capacity and markets. Seawater desalination requires more energy than to desalt brackish water and it is therefore more expensive to desalt seawater. Hence seawater desalination should get a higher support than brackish water desalination. But on the other hand it is less ecologically harmful to desalt brackish water than seawater, because less energy and therefore smaller plants are needed. The support for seawater should be a bit higher than the support for brackish water. However, the incentive for desalting brackish water has to be higher so that if both options are possible, the brackish desalination option is chosen.

Table 11: Adaptation of a support scheme to technology, water quality and capacity

	support	incentive	degression
More developed technology	low	-	low
Less developed technology	high	-	high
brackish water	medium	high	-
Seawater	high	low	-
Large capacity	low	-	-
Medium capacity	medium	-	-
Small capacity	high	-	-

- Remove administrative and legal barriers

A support scheme should be implemented in a way that little bureaucratic effort is needed from the investor. A contact institution should be implemented, where the investor gets all the information he needs and where he can apply for the support scheme. The investor should only have few bureaucratic steps to do to be supported.

- Existing capacities and new capacities should not be mixed

The aim of the support scheme is to encourage the installation of new capacities. Already existing capacities probably are competitive and do not need support, otherwise they would not have been built.

- Regular amendment to adapt the support scheme to market changes

While implementing a support scheme, assumptions will be made about how the cost of RE-desalination will change in the future. Therefore the support scheme needs to be reviewed regularly: First after two years and then every 4 years. It should be then examined how well the support scheme works and if the incentive appropriate. If the incentive is too low, not enough RE-desalination plants will be built. If the incentive is too high more desalination plants will be built than is efficient for the society. Based on this examination the scheme should be amended.

(see also Ragwitz, 2008, p.13)

- No over support

Although RE-desalination is very important and should be supported it should not be over supported. RE-desalination has little environmental impacts, but still has some. The aim should be to install RE-desalination plants only in locations where no other solution like water saving or recycling is possible.

4.2.2. Including in existing support schemes

Several support schemes already exist for the production of electricity or heat with renewable energy sources and for desalination. As RE-desalination first produces energy with RES, to then use this energy to desalt water, it could be included into support schemes for energy from RES and for desalination. To include RE-desalination into support policies for RES, small changes have to be made in the existing acts, to make owners of RES that use the energy produced to desalt water, eligible. These support schemes could be a feed-in tariff like the one in Spain, a quota scheme like the one in Italy, an investment subsidy etc. The production of electricity and the desalination process are seen individually. It is metered how much energy is produced by the renewable energy source. A support is given according to the RES technology and the kWh produced. For what purpose the energy produced is used does not matter in this scheme, but it is possible to use it for desalination.

With an existing feed-in tariff for electricity the idea is that the RE-desalination plant operator gets a bonus for the electricity he produces to desalt water. The German feed-in tariff system (3.1.1) can be taken as an example. Since 2009 a bonus is paid if the electricity produced by a PV plant is consumed locally. If the owner uses electricity from renewable energy to desalt water, it is similar to self use of electricity. It could for example be imagined that a private PV owner in Germany uses the electricity from his roof to operate a small RO system to desalt water. According to the law he would get a feed-in tariff. This option should be introduced to feed-in tariff mechanisms from countries that have a market for desalination.

With a very small change of the law some RE-desalination technologies could be included into quota schemes for electricity. It is metered how much kWh are produced by PV or wind turbines etc. For this produced kWh the operator gets certificates that he can sell, but he uses the electricity to desalt water.

Some countries subsidize the installation of solar thermal collectors through investment subsidies. Solar thermal collectors that are installed for desalination purposes should also be eligible to get the support.

Other support schemes for RES exist. In most of them RE-desalination could be included with only minor changes of the policies.

Precondition in the country where the support scheme should be implemented

A support scheme for RES has to exist in this country.

Example (feed-in tariff)

As an example a brackish water reverse osmosis plant with photovoltaic as energy source (BWPV-RO), is taken. More explanation to the data used can be found in Annex I.

Table 12: Assumptions for the example to include RE-desalination into an existing feed-in tariff

Water price:		1.53€/m³
Energy consumption:		2kWh/m³
WGC for BWPV-RO:	**Worst case**	5.73€/m³
	Best case	2.86€/m³
Feed-in tariff (Bonus) for PV:		0.25 €/kWh

<u>Worst case</u>

Feed-in tariff/ m³ = 0.25 €/kWh *2kWh/m³ = 0.50 €/m³

→WGC = 5.73 €/m³ - 0.50 €/m³ = **5.23**€/m³

<u>Best case</u>

Feed-in tariff/ m³ = 0.25 €/kWh *2kWh/m³ = 0.50 €/m³

→WGC = 2,86 €/m³ - 0.50 €/m³ = **2.36**€/m³

In this example including BWPV-RO in an existing feed-in tariff for electricity generated by photovoltaic would not be enough to make the technology competitive, because the water generation cost is higher than the water price.

Evaluation

The advantage of making RE-desalination eligible for existing support schemes is that only little changes have to be made in already existing laws. This can be made very quickly and with little effort. But on the other hand also disadvantages exist. What RE-desalination technologies are supported and the amount of support, depends on the RES supported. Therefore it is not sure that all promising RE-desalination technologies are supported. Furthermore, the amount of support is not adapted to the costs of RE-desalination.

Table 13: Advantages and disadvantages of including RE-desalination in existing support schemes

Advantages	Disadvantages
• Very easy to implement in a country that already has a support scheme	• The amount of support is not adapted to RE-desalination • Only RE-desalination is supported for which RE source exist a support scheme →Little technology diversification; Not all technologies are supported

4.2.3. Feed-in tariff for water

In this case a feed-in tariff system is developed for fresh water. For every m³ of produced fresh water, the RE-desalination plant operator gets a bonus from the water grid operator. This bonus is fixed for a defined time frame. The extra costs from the scheme are passed on to the water consumer. The water grid operators are the municipalities. The countries are divided into regions in which the municipalities balance their expenses, so that not one municipality has to bear more extra cost from the scheme than another. The expenses are not balanced across the whole country to reflect unequal water availability in different regions. Water scarce regions should have higher water prices than water abundant regions. To be able to implement such a scheme, every RE-desalination plant has to be equipped with a water meter. The bonus should vary regarding different technologies, capacities and raw water quality. To get a bonus it does not matter if the RE-desalination plant operator feeds the water into a water grid, sells it directly to the consumer or uses it for its own purpose. Because the extra costs from the support schemes are passed on to the consumer, a problem could be that the water price could rise to a value that makes it impossible for some people to buy water. But it is unlikely that this will happen in southern Europe, because desalination provides only a share of the freshwater and RE-desalination only a share of the desalinated water. Moreover, if a lifeline rate is implemented, the vital amount of money should stay low. But to make sure the water price cannot rise limitless, a cap should be determined. If the price for the vital amount of water reaches this level, no new plant can get the bonus. To avoid reaching the cap, the water price has to be monitored. When a large increase of the water price is noted and the cap is approached, the policy has to be amended and the bonus for new plants lowered. Moreover, a water quality standard is needed. Only operators that fulfill the quality standard can get the bonus.

Precondition in the country where the support scheme should be implemented

The country should have a centralized water system. All water generation and consumption should be registered in a central place.

Example

Table 14: Assumptions for the example of a feed-in tariff for water

Water price:		1.53€/m³
WGC for BWPV RO:	**Worst case**	5.73€/m³
	Best case	2.86€/m³

The bonus for water should be as high that the water generation cost is equal to the water price. The WGC needs to be reduced to 1.53€/m³ by using the feed-in tariff. What amount of tariff has to be given is calculated in the next lines.

<u>Worst case</u>

5.73€/m³- 1.53€/m³ = **4.2 €/m³**

<u>Best case</u>

2.86€/m³- 1.53€/m³ = **1.33 €/m³**

Evaluation

Table 15: Advantages and disadvantages of a feed-in tariff for water

Advantages	Disadvantages
• Good differentiation regarding technologies, capacities and raw water quality • Easy to understand for the investor • Low risk for the investor • The water price reflects the cost	• The implementation needs a lot of effort: Safety of quality and supply • Water consumption might not be metered in remote areas → installation of meters

The advantages of this scheme are that it is easy to differentiate regarding technology, capacity and raw water quality and that the bonus can be adapted easily to the WGC. Therefore it is a strong incentive. Moreover, it is very easy to understand for the investor. Because the bonus plant operator get is fixed for several years, the investment has a low risk, which makes it attractive. As the support that RE-desalination plant operators get is passed on to the consumer, the water price reflects the cost.

A disadvantage is that water consumption might not be metered in remote areas where RE-desalination has a great potential. Water meters would have to be installed, which can become very expensive. Furthermore, it is expensive and a lot of effort to implement this policy. A certification body needs to be implemented to make sure only plants that guarantee an excellent water quality get the bonus.

4.2.4. Quota scheme for water

The government fixes a certain share of the desalinated water that has to be produced by RE-desalination. Then a certificate market is created. RE-desalination fresh water producers get certificates and sell them to fossil fueled desalination fresh water producers. This results in a decrease of the water price from RE-desalination and in an increase of the water price from fossil fueled desalination. In total the price for desalinated water rises, because more expensive technologies enter the market. Because of the price increase for desalinated water, the total water supply will decrease and the water price will rise. The extra cost from the scheme is divided between all water consumers.

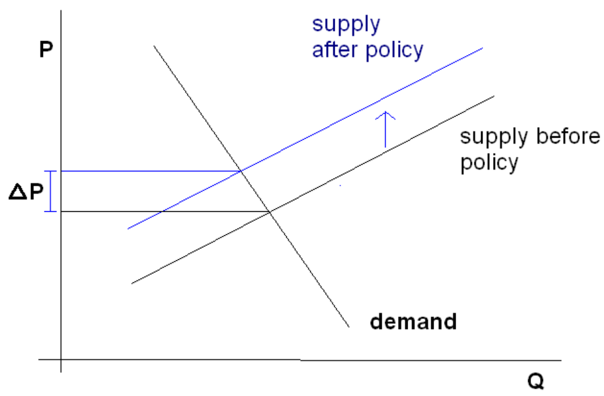

Figure 3: Influence of the quota scheme on the water price

A problem could be that the water price could rise to a value that makes it impossible for some people to buy water. It is unlikely that this will happen in southern Europe, because desalination provides only a share of the freshwater and RE-desalination only a share of the desalinated water. But to make sure the water price cannot rise limitless a cap should be determined. If the price for the vital amount of water reaches a certain level the quota has to be lowered to the percentage that is already reached. To promote all promising technologies factors have to be included into the quota scheme. If for example the cost for water from PV-RO is 5 times higher than the cost for water from wind-RO, wind-RO would get the factor 1 and PV-RO the factor 10. In this case wind-RO would gets 1 certificate per m^3 produced while PV-RO gets 5 certificates.

Precondition in the country where the support scheme should be implemented

The country should have a centralized water system. All water generation and consumption should be registered in a central place.

Example

Table 16: Assumptions for the example of a quota scheme for water

Water price:		1.53€/m³
WGC for BWPV RO:	**Worst case**	5.73€/m³
	Best case	2.86€/m³

If a quota is set for RE-desalination the price of certificates will rise until the cheapest RE-desalination technology is competitive and this technology will be installed. If each technology gets a factor and the factors are well adapted, the price of the certificates will rise until every promising technology is competitive. If PV-BWRO gets a factor of 1, the price of the certificates would rise to:

Worst case BWPV-RO

5.73 €/m³ - 1.53€/m³ = **4.2 €/m³**

Best case BWPV-RO

2.86 €/m³ - 1.53€/m³ = **1.33 €/m³**

Evaluation

Table 17: Advantages and disadvantages of a quota scheme for water

Advantages	Disadvantages
• It is easy to achieve a certain target • The price for the certificates is adapted automatically to the production cost	• Little experience (In experience it is in most cases not working effectively) • Difficult to implement / Difficult to find the right quota • The price of the certificates is difficult to predict → higher risk for the investor→ higher costs • Promotes large plants. Not suitable for small plants with private owners • No incentive when the quota is achieved • More complex system as the others, because a market for water and one for certificates is needed.

One advantage is that all technologies can be promoted if factors are included. Also it is trivial to achieve a percentage target because it is directly set. Furthermore, the price for the certificates is adapted automatically to the production cost. If the cost of RE-desalination falls, more plants will be built and more certificates will be on the market. Therefore the price of certificates will fall until it has the right price to cover the extra cost from RE-desalination.

The disadvantages are that only little experiences have been made with quota schemes in developing the renewable energy market and in most cases the scheme was not implemented effectively. Therefore it can be supposed that it is more difficult to implement a quota scheme than a feed-in tariff. The price of the certificates varies with the demand and supply. Therefore investors cannot predict exactly the support they will get from this support scheme and have a higher risk, which leads to higher WGC. It is difficult for private investors in small plants to participate in the certificate trading. Therefore only large plants are promoted. Once the quota is achieved no incentive to invest in more plants is given. The system is more complex than other support schemes, because two markets are needed: One for water and one for certificates.

4.2.5. Production subsidy or tax incentive

A subsidy for RE-desalination could be imagined as following: For every m³ of water a RE-desalination plant produces the owner gets a fixed amount of money. The subsidy has to be so high that the producer can cover his cost, while he can offer his water to a competitive price. Instead of a subsidy it could also be imagined to give a tax credit of the same amount. This support scheme can be diversified regarding technology, capacity and raw water quality very easily. Only RE-desalination plants that fulfill a water quality standard should be eligible. To raise the money for the subsidy, the state could tax fossil fueled desalination. If this is done the water price would not be distorted, but the water cost reflected. However, as fossil fueled desalination is widely subsidized today first the subsidies have to be removed, before thinking of introducing taxes.

Example

Table 18: Assumptions for the example of a production subsidy

Water price:		1.53€/m³
WGC for BWPV RO:	**Worst case**	5.73€/m³
	Best case	2.86€/m³

To become competitive on the Canary Islands a PV-RO investor would need to get a subsidy or a tax credit of:

Worst case BWPV-RO

5.73€/m³- 1.53€/m³ = **4.20 €/m³**

Best case BWPV-RO

2.86€/m³- 1.53€/m³ = **1.33 €/m³**

Evaluation

A production subsidy is very simple to implement and easy to understand for investors. Furthermore, it is flexible. The amount of subsidy can be adapted to different technologies, capacities and raw water qualities. A production subsidy supports the production of freshwater and therefore supports efficient plants. On the other hand this support scheme can get very expensive for the government if a large capacity of RE-desalination plants is installed. This might lead taxes raises, which has a very negative perception by the population. In this case, it might be better to use a feed-in tariff. It has a similar effect, but the price is not paid as tax but as an increase of the water bill. (European Wind Energy association, 2005, p. 42)

Table 19: Advantages and disadvantages of a production subsidy or tax incentive for water

Advantages	Disadvantages
• Very simple support scheme • Easy to comprehend for the investor • Flexible, can be diversified regarding technology, capacity and raw water quality • Supports efficient plants	• Can get very expensive for the government if a large capacities of RE-desalination plants is installed • Might lead to a tax increase

4.2.6. Investment subsidy or tax incentive

RE-desalination has high investment costs. On the other hand the operation costs are low, because the energy used is for free. Therefore a good scheme to support RE-desalination would be an investment subsidy. The investor does not have to bear the high investment cost in total. And of course it reduces the water generation cost. The aim is that the state pays a share of the investment cost and the RE-desalination can now be competitive. Instead of a subsidy also a tax credit could be given. Both possibilities have the same impact on the budget of the investor.

Example

Table 20: Assumptions for the example of an investment subsidy

Water price:		1.53€/m³
Investment cost:		41683€
WGC for BWPV RO:	**Worst case**	5.73€/m³
	Best case	2.86€/m³

<u>Worst case</u>

The BWPV RO plant of our example would have to have an investment cost of 5500€ to have a WGC of 1.53€/m³ (see Annex 2). This means that the plant would need an investment subsidy of **85%** of the investment cost. If installation costs are included into the eligible costs, the share of investment subsidy would fall.

<u>Best case</u>

The BWPV RO plant of our example would have to have an Investment cost of 18700€ to have WGC of 1.53€/m³ (see Annex 2). This means that the plant would need an investment subsidy of **45%** of the investment cost.

Evaluation

Table 21: Advantages and disadvantages of an investment subsidy or tax incentive for water

Advantages	Disadvantages
• Very simple support scheme • Easy to comprehend for the investor • Flexible, can be diversified regarding technology, capacity and raw water quality • No extra cost for the water consumer • The investor does not have to bear the large investment cost	• Does not support efficient plants • Can get very expensive for the government if a large capacity of RE-desalination plants is installed • Might lead to a tax increase

Similar to a production subsidy an investment subsidy is very simple to implement and easy to understand for investors. The amount of subsidy can be adapted to different technologies, capacities and raw water qualities, which makes it flexible. Furthermore, the investor does not have to bear the large investment costs.

But an investment subsidy supports the installation of capacity and not production of freshwater. This can lead to inefficient plants. Therefore it is only advisable to implement an investment subsidy in combination with a support scheme that promotes the production of freshwater. Moreover, this support scheme can get very expensive for the government if a large capacity of RE-desalination plants is installed. To compensate for the high costs, the government might have to raise taxes, which is perceived very negatively by the population. (European Wind Energy association, 2005, p. 42)

4.2.7. Obligation

A state could make a law that obligates desalination to be operated with RES. Every new desalination plant would work with renewable energies. A penalty has to be implemented for not fulfilling the obligation. This penalty has to be higher than the extra cost for a RE-desalination plant to be effective.

Evaluation

With an obligation every new desalination plant will use renewable energies and no harmful fossil fueled desalination plants will be built anymore. But it would raise the price of desalinated water substantially and therefore the price of water in regions that use desalination. Therefore it is only an option in combination with other policies that lower the water price. Maybe a combination with a subsidy like it is made in Germany (MAP + EEWärmeG), where an obligation is combined with an investment subsidy to promote heat from renewable energy sources (see chapter 3.2). A disadvantage is that market mechanisms cannot work anymore, and even in situations where it is extremely expensive to operate a desalination plant with renewable energies, it is mandatory. If the obligation is implemented alone and not combined with another support scheme, only the cheapest RE-desalination technology will be promoted.

Table 22: Advantages and disadvantages of an obligation to use RE-desalination

Advantages	Disadvantages
• Every new desalination plant will work with renewable energies	• Even if it is very expensive to install RE-desalination the investment has to be made • The water price rises limitless • Does not promote every kind of RE-desalination

5. Evaluation of the support schemes and recommendations

To evaluate the different support schemes for RE-desalination a value benefit analysis is made and a combination of support schemes is suggested. Production and investment subsidies are evaluated and not tax incentives. This has the reason that subsidies and tax incentives have the same impact on the budget of the investor and of the state, but subsidies have the advantage that they are easier to understand.

5.1. Value Benefit analysis

A value benefit analysis is made to find out which support policy has the most potential to promote renewable energy driven desalination.

5.1.1. Methodology

A value benefit analysis is the analysis of alternatives. It has the aim to order different alternatives that cannot be compared regarding purely monetary aspects. Instead alternatives are compared regarding subjective values. The first step of the analysis is to define the objective that should be attained with the alternatives (A). To be able to evaluate how well an alternative fulfills the objective, the objective is divided in sub objectives also called desired criteria (C). Moreover, K.O. criteria need to be defined, to exclude alternatives that are pointless to evaluate. Once the desired criteria are determined they have to be weighted on an ordinal scale, for example on a scale of 5 points. The criteria are ordered relatively to their importance. Different criteria can have the same value, if they have the same importance. Now it has to be evaluated how well the alternatives fulfill the criteria. Again ordinal points (p) are given to express this. When all this is done the value of the alternatives is calculated by multiplying the points of the alternatives with the weight (W) of the criteria. The alternative with the highest value is the one that fulfills best the objective.

Table 23: General structure of a value benefit analysis

Criteria	Weight [W]	alternatives					
		A1	A1*W	A2	A2*W	A3	A3*W
C 1	w1	p1	p1*w1	p4	p4*w1	p7	p7*w1
C 2	w2	p2	p2*w2	p5	P5*w2	p8	p8*w2
C 3	w3	p3	p3*w3	p6	p6*w3	p9	p9*w3
Result			p1*w1+p2*w2+p3*w3		p4*w1+p5*w2+p6*w3		p7*w1+p8*w2+p9*w3

The disadvantage of this analysis is that the result is subjective. Different decision makers might get different results depending on their preferences. But the big advantage and the reason this method is used is that it is very flexible regarding the alternatives and the criteria. Not only monetary qualities can be compared. Moreover, not comparable alternatives can be made comparable by choosing common criteria. (Zangenmeister, 1971, p.45, 60)

5.1.2. Analysis

No K.O criterion has been identified for this analysis. Therefore all support schemes developed in chapter 4 are evaluated.

Objective

The desalination plants until 2016 are expected to be worth over $64 billion. The RE-desalination community is targeting a 3-5% share of that market, so RE-desalination over the period of the next 7 years is worth $2 -3 billion; a market large enough to attract the interest of major players who will catalyze fast developments. (ProDes, 2010, p.52) An effective support scheme for southern Europe that helps reaching this target is searched in this value benefit analysis.

Desired Criteria

For evaluating the different support schemes, several criteria have been identified. Following the different criteria are explained. Furthermore, questions are formulated that helps to evaluate the different alternatives with respect to the criteria.

- Investor confidence
    - Easy to use and to understand

Only if the support scheme is easy to understand and transparent, investors can rely on it and will undertake investments in RE-desalination. (European Wind Energy association, 2005, p. 42)

Is it easy for the investor to understand how he can benefit from the support scheme?
Is it easy for the investor to participate in the support scheme?

-
    - Low perceived risk and bankability

The investor confidence depends on the risk they perceive by using the support scheme. If they know from the beginning on what money they get in which time period it is very easy for them to predict their cost and to know if the investment will be cost-efficient. The higher the risk that the investor has to bear the higher the cost he will estimate and the fewer investors will invest. Moreover, investors can get credits from banks more easily if the bank knows exactly what income the investor will get from his investment. (see European Wind Energy association, 2005, p. 43)

Does the investor exactly now how much money he will get from the support scheme?

- Easy to implement

If a support scheme is easy to implement. Countries will more likely do so. For example if RE-desalination can be included in an already implemented support schemes, this is very easy for a state. If a completely new system has to be implemented it will need a lot of money and time to do so. Moreover, a new system is more susceptible to problems, due to lack of experience.

Is it easy to implement the support scheme?

- Diversification of Promotion
  - Promotion of a wide range of promising technologies

Each promising technology should be supported. The aim is that every technology gets a chance, because it is difficult to know today which technology has the most potential in the future. If every technology gets the chance to enter the market, it will show in the long run which technologies will be the most efficient. (see European Wind Energy association, 2005, p. 42)

Is a wide range of technologies supported?

  - Promotion of a wide range of capacities

RE-desalination has a wide range of capacities. Small plants with a capacity of few liters per day for one family exist as well as large plants with capacities of hundred thousands of m³ per day with the aim to produce fresh water for whole cities. All plant sizes will play an important role in overcoming the water problem. Large plants will be financed by huge companies with a lot of capital and the possibility to get cheap loans. In contrast small plants will probably be financed by individuals with little capital and that are only get expensive credits. Both individuals and big companies should be able to benefit from the support scheme.

Is it easy for individuals to participate in the support scheme?
Is it easy for big companies to participate in the support scheme?
Are individuals helped with the huge investment costs?

- Promotion of productivity and not only capacity expansion

Another criterion for the effectiveness of a support scheme is that the scheme supports low cost production and not only capacity expansion. (see European Wind Energy association, 2005, p. 44)

Is productivity supported?

- The support is paid by the right party

Depending on the support scheme different groups of the society have to bear the extra costs from the support schemes: The Water consumer, the electricity consumer or the tax payer. The question to be addressed is: Who should pay the extra cost? The answer that comes to mind first is the water consumer, because desalination is used to produce fresh water for the water consumer therefore he should have to pay for making this in a renewable way. The reason the energy consumer should pay the support schemes is that energy is required to produce desalted water. Desalting water with renewable energy can be seen as self use of energy. For example the self use of renewable electricity permits to get a feed-in tariff in Germany. As RE-desalination self consumes renewable energy, it could be treated as a renewable energy sources. The energy produced for RE-desalination should be eligible in support schemes for RE energy and it is justified that energy consumer pay the support scheme for RE-desalination. Using RE-desalination benefits the whole society. Because it replaces fossil fueled desalination and therefore avoids negative externalities. By making the tax payer pay, everyone contributes to the protection of the climate, depending on its possibilities.

Who should pay the support?

- The water price is not distorted

After the Water Framework Directive the water price should reflect the water generation cost. This should also be the case when RE-desalination is supported.

Is the water price distorted by the support scheme?

Application

The different criteria have been weighted with weights from 1 to 5, where 5 means the criterion is very important, while 1 means the criterion is not very important. Only the values 3, 4, and 5 have been assigned in this analysis, because all criteria are deemed to be rather important. The most important criteria are the promotion of a wide range of technologies and capacities. Only if a large diversity is supported it can be assured that no technology with potential is excluded. Moreover, in different applications where desalination is needed different requirements have to be fulfilled and different technologies and capacities are best. The second most important criteria are that the investor has a low risk, that

Table 24: Evaluation of the suggested support schemes in a value benefit analysis

Criteria		Weight	Weight [%]	Alternatives					
				Include in existing policies	Feed-in tariff water	quota scheme water	productions subsidy	investment subsidy	obligation
Investor confidence	easy to use and to understand	3	9.7	4	4	3	5	5	5
	low perceived risk/ bankability	4	12.9	4	4	2	4	5	2
easy to implement		3	9.7	5	3	2	5	5	3
Diversification of Promotion	Promotion of a wide range of promising technologies	5	16.1	2	4	4	4	5	1
	Promotion of a wide range of capacities	5	16.1	2	4	3	4	3	4
Promotes productivity and not only capacity expansion		4	12.9	3	5	5	5	1	5
The support is paid by the right party		3	9.7	3	5	5	3	3	5
The water price is not distorted		4	12.9	3	5	5	3	3	5
result		31	100	26	34	29	33	30	30
Weighted result				96	132	113	127	115	112

productivity is supported and that the water price is not distorted. The Investor needs to be confident into the support scheme. He has to be able to know in advance if his investment in RE-desalination will benefit him more than another investment. Moreover, a bank will give him a credit more likely if he can predict how much he will earn with the support scheme. The aim of the support scheme is to produce a maximum of fresh water with as little as possible resources. Only productive installations are requested. A little less important are that the scheme is easy to use and to understand, easy to implement and that the support is paid by the right party. Of course this evaluation is subjective and another person might weight the criteria slightly different.

To express how well the criteria are matched by the different support schemes a scale of 5 points has been chosen. 5 nuances to evaluate the support schemes seems the right number because a larger scale is found to be too difficult to apply. By a smaller number of nuances in contrast differences between support schemes could not be indicated in the right extent. The points given to the various support schemes with respect to the selected criteria are summarized in table 24. In the following paragraphs the choices made are explained in more detail.

The support schemes that are the easiest to understand are production subsidies, investment subsidies and obligations. With the subsidies the investor knows that he gets money from the state. Under an obligation it is very clear to investors that they have to power their new desalination plants with RES. Therefore these three alternatives have been given 5 points. A bit harder to understand is the feed-in tariff. The investor knows he gets a support, but as the mechanism is relatively new it is less well known by the investors and therefore not as good to understand. The most complicated support scheme is the quota scheme. Two markets are needed for this scheme, a water market and a certificate market. This makes it harder for investors to understand it. The quota scheme is given 3 points. How easy to understand the inclusion in existing support schemes is, depends on the existing support schemes for energy. A quota scheme for electricity would be given 3 points, a feed-in tariff 4, and subsidies 5. The average is 4 points and is given to this alternative.

The risk an investor has to bear depends on his knowledge about the exact amount of money he will get. The price of the certificate in a quota scheme depends on demand and supply on the RE-desalination market and is therefore hard to predict. With an obligation the only money the investors get is the water price. Due to the obligation the water price will rise but it is not predictable how much. Because of these uncertainties the two support schemes, get 2 points. With a feed-in tariff and with a production subsidy it is determined in advance what amount of money will be paid per m^3 for several years. The only thing that is not known by the investor is how well the plant will perform and therefore he has to assume the amount of water that will be produced. The risk for the investor is very low and the schemes get 4 points. With the investment subsidy the investor can predict exactly how much support he will get. This alternative gets 5 points. What risk an investor has to bear with the inclusion in existing support schemes is again depending on the existing support schemes for energy. An investment subsidy would be given 5 points, a feed-in tariff and a production subsidy 4 points, and a quota scheme would be given 2 points. The average is 4 points and is given to this alternative.

Production and investment subsidies are very easy to implement. The creation of a feed-in tariff for water is more difficult, because the water grid operators have to be included into the scheme. When an obligation is implemented it has to be monitored if all desalination plants are powered with RE-desalination. Implementing a quote scheme is more complicated than implementing a feed-in tariff or an obligation. It has to be monitored if the quota is satisfied and a certificate market has to be created. Including RE-desalination in an existing support schemes is much easier than implementing a new feed-in tariff or a quota scheme.

With an obligation only the cheapest RE-desalination technology is promoted. Therefore this scheme only gets 1 point. The existing support schemes are not adapted to RE-desalination and depending on the support schemes that already exist in the target countries different technologies will be supported. It is probable that some technologies do not get a support and that others do not get enough support. Therefore this alternative only gets 2 points. All other support schemes are designed in a way that they support a wide range of support schemes. With support schemes that give a support per m^3 of water produced it might be difficult to meter how much water has been produced. Especially with easy solar stills no water meter can be included in the design. Therefore they only get 4 point. An investment subsidy on the other hand is completely flexible about the technologies and gets 5 points.

Again the existing support schemes are not adapted to RE-desalination and depending on the support schemes that already exist in the target countries different capacities will be supported. It is probable that some capacities do not get a support and that others do not get enough support. Therefore this alternative only gets 2 points. Investment subsidies can promote every capacity and production subsidy and feed-in tariffs have the problem of the water metering. Therefore they get 4 points. The obligation also gets 4 points, because everybody can participate in this policy, but individuals that invest in small plants are not helped with the huge investment cost. Quota schemes have an extra problem. To participate in a certificate market is very difficult for individuals. It is more likely that big companies use the certificate market. Usually big companies invest into big plants. Therefore quota schemes only promote medium and large scale plants and get 3 points.

Productivity is supported when a support is given for the output, in this case m³ of fresh water. Feed-in tariff, quota scheme and production subsidies all give support per m³ water produced and therefore get 5 points. As people have to power desalination with RES and this is expensive, they are more likely to invest in efficient plants and obligations also get 5 points. An investment subsidies on the contrary gives support for capacity installation and not for productivity. It does not fulfill the criteria and therefore only gets 1 point. In the existing support schemes investment based and productivity based support schemes are contained. Therefore there get the average point between the two.

It can be perceived as unfair by the tax payer and the energy consumer if they have to pay the support for the water production. But as explained under this criterion it has some justification. Therefore inclusion in existing support schemes and subsidies get 3 points. The water consumer should pay the support and therefore feed-in tariff for water, quota scheme for water and the obligation get 5 points.

The water framework directive says that in all countries of the EU the water price should reflect the water generation cost. Therefore the support scheme should not distort the water price. The water price reflects the cost with the feed-in tariff for water, the quota scheme for water and the obligation. Therefore these three options get 5 points. The other option distorted the water price. But the water price is already influenced by introducing a support scheme. Without a support scheme the water would be desalinated with fossil fuels and the water price would be x. With a support scheme like a feed-in tariff or a quota scheme for water the water price rises to y. By using one of the other support schemes the water prices stays at x. Furthermore, the support scheme is only for a transition period. Because it can be seen under two ankles, the other support schemes get 3 points.

5.1.3. Result

In the value benefit analysis the feed-in tariff for water received the most points. Second and third are production and investment subsidies respectively. The value benefit analysis should only be seen as an indicator. It is a subjective analysis and if it is done by another decision maker the alternative order might be different. Therefore each country that wants to implement a support scheme for RE-desalination should repeat this analysis. Following steps should be taken: 1) Review desired criteria and K.O. criteria. Criteria could be added or removed; 2) Weight the criteria; 3) Give points to the alternatives. For different countries different support schemes can be best. For a country that already uses a quota scheme for

RES it is maybe easier to implement a quota scheme for water as a feed-in tariff because experience an infrastructure for this policy already exist. Also the population of different countries might have negative or positive perceptions of support schemes, which makes it harder or easier to implement one or another support scheme. In some cases the best option might be to combine support schemes. This is explained in the next chapter.

5.2. COMBINATION OF SUPPORT SCHEMES

In the previous part the support schemes have been compared to each other. But it could be an option to implement two support schemes together to have the advantages of both.

The best option found in the value benefit analysis is the feed-in tariff for water. However, this support scheme has the disadvantages that it cannot support simple solar stills effectively. Moreover, RE-desalination plants are extremely investment cost intensive, while the operation cost is low, because renewable energies are for free. Especially individuals that are interested in small scale RE-desalination might not be able to bear the investment cost. To overcome this problem it could be combined with an investment subsidy. Investment subsidies also achieved a very good result in the value benefit analysis and can resolve the problems of the feed-in tariff for water. A feed-in tariff for water could be implemented for all technologies, capacities and raw water qualities. In addition an investment subsidy could be implemented for small capacities, especially for solar stills for which the water production cannot be metered and which can therefore not be included in the feed-in tariff for water.

Although an obligation got fewer points in the benefit value analysis than other policies it can be very interesting in combination with another support scheme. The advantage of an obligation is that it will increase the share of RE-desalination faster than with any other policy. However, the huge disadvantages of the obligation is that the price of water will raise more than with the other policies and that only the cheapest RE-desalination technology is promoted. To overcome this, the obligation could be combined with a subsidy. In Germany to promote the generation of heat with RES an obligation has been implemented in combination with an investment subsidy. To combine an obligation with an investment subsidy for RE-desalination would have the advantage that the investors are helped with the high investment cost and therefore it is especially for individuals easier to invest in RE-desalination. But investment subsidies do not promote efficient plants. Another possibility is to combine an obligation with a production subsidy. The advantage of combining it with a production subsidy is that efficient plants are supported. However, the disadvantage is that the investors are not helped with the high investment cost and therefore it is difficult for individuals to invest in RE-desalination. As the advantages of the one are the disadvantages of the other it is difficult to decide which option is better. And it has to be decided for every country individually.

6. CONCLUSION /OUTLOOK

The aim of this paper is to suggest support schemes to promote the market introduction of RE-desalination especially in southern Europe.

Before implementing a support scheme the target countries should abolish their subsidies on water so that the water price reflects the real water price. This is also demanded in the Water Frame Work Directive of the European Union. To still make water available for everyone target countries should introduce a life line rate pricing system. The lifeline rate makes water available for everyone but still reflects the true water cost.

After reviewing existing support policies for electricity, heat, desalination and RE-desalination, different requirements have been indentified that should be met to establish a good working support scheme. These requirements are: The support scheme has to be a long term incentive to give security to the investors. To encourage this, a long term, sufficiently ambitious but realistic target should be defined for the share of RE-desalination in every target country. It is also important to include a degression of tariff and to define an end date for the support scheme, to make RE-desalination competitive in the future. Differentiation between technologies, capacity and raw water quality is essential, to promote a wide range of plants that find there necessity in different applications. Administrative and legal barriers have to be removed. Existing capacities and new capacities should not be mixed. The support scheme should be amended regularly to adapt it to market changes. Furthermore RE-desalination should not be over supported. Independently from the support scheme chosen these recommendation should be included in the support scheme.

In chapter 5 a value benefit analysis was made. The outcome of this analysis is that a feed-in tariff for water is the best support scheme. The second and third best options are production subsidies and investment subsidies respectively. This result is only an indicator and it has to be checked for every country individually, which support scheme is best for them. Target countries should choose their own K.O. criteria and weight the desired criteria regarding their own preferences. Then they should value again the alternatives. Maybe even a completely different support scheme as those presented in this study could be developed.

The feed-in tariff has the disadvantage that it is not well suited to support simple solar still desalination plants. Moreover, RE-desalination plants are extremely investment cost intensive, while the operation cost is low, because renewable energies are for free. Especially individuals that are interested in small scale RE-desalination might not be able to bear the investment cost. To overcome this problem the feed-in tariff could be combined with an investment subsidy. Investment subsidies also achieved a very good result in the value benefit analysis and can resolve the problems associated with the feed-in tariff for water.

Another promising combination of support schemes could be an obligation combined with either a production or an investment subsidy. This combination has the advantage towards the combination feed-in tariff/investment subsidy that it assures that every new installed desalination plant will be powered with RES. It will therefore lead to a faster increase of the share of RE-desalination in the desalination market.

If a target country cannot, does not want to, or needs more time to implement a support scheme for RE-desalination, renewable energy driven desalination could at least be included in existing policies for energy to get some support.

This study suggests several possibilities to promote renewable energy driven desalination and demonstrates how to evaluate their potential for a given application. However, a general solution for every case cannot be given. Every target country should analyze which of the proposed schemes is best in their specific case.

To implement a support scheme it has to be known which technologies should be supported and how much these RE-desalination technologies cost. A detailed analysis has to be made to classify the RE-desalination technologies into the 3 phases: R&D phase, development phase, and market introduction and diffusion phase. Only the technologies in the market introduction and diffusion phase should be supported by the schemes presented in this study. The other technologies need different support schemes today, but should be included in the market introduction and diffusion scheme once they reached this phase. The real cost of RE-desalination is not known, but it is needed to define the amount of support RE-desalination needs. A proper study has to be made to find out the cost depending on technology, capacity and raw water quality.

LIST OF TABLES

List of figures

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ANNEX 1#

In this annex the assumptions are explained that have been made for the examples in chapter 4.

Example assumptions

Water price Canary Islands:		0.83 - 2.24 €/m3 → 1.53€/m^3 (V. Subiela, personal communication 12.15.2009)
Energy consumption BWPV-RO:		2kWh/m^3
WGC for BWPV RO (6.2m^3/day):	**worst case**	2.86€/m^3 * 2 (for underestimation) = 5,73€/m^3
	best case	2.86€/m^3
Feed-in tariff (Bonus) PV:		0.25€/kWh (Germany)

Water cost Canary Islands:

To know to what price freshwater from RE-desalination has to be sold to be competitive the price of water has to be known. In this example the average price of the Canary Islands is taken. The Canary Islands are a market for RE-desalination and therefore it makes sense to take this price. This price probably does not reflect the true water cost on the Canary Islands, the true price is expected to be higher. As the water cost should be reflected in the water price in Europe, it is probable that the water price will rise and that less support will be needed.

WGC BWPV RO:

As technology example brackish water desalination with PV-RO is taken. This technology is already well developed and it is the most frequent installed RE-desalination technology in the world. Brackish water is cheaper to desalinate and therefore the first option to promote. A plant with a capacity of 6.2m^3/d from the company Trunz is taken. For the worst case the WGC are multiplied by 2 due to the underestimation of WGC explained in chapter 2. In the best case scenario the price is taken as it is given by the company.

Energy consumption:

The energy consumption that corresponds to the BWPV-RO plant in the WGC is taken.

Feed-in tariff (Bonus) PV:

As assumption for the feed-in tariff for the self use of electricity from PV, the German self use bonus is used. Spain does not have a self use bonus. German and Spanish feed-in tariffs are close enough that a similar bonus can be assumed in Spain. Furthermore, this example is only used to get an overview over how the support schemes might work for RE-desalination. The Idea is not to give correct data, but to make support schemes comparable.

ANNEX 2#

In this annex it is explained how the investment subsidy has been calculated in chapter 4.2.6.

Real cost

annuity method				
End of the year	Investment	maintenance		
0	41683 €		i = adequate target rate=	0.05
1		1000 €	Operation days=	360 d
2		1000 €	Daily capacity=	6.2 m³/d
3		1000 €	Annual capacity=	2232 m³/a
4		1000 €		
5		1000 €		
6		1000 €		
7		1000 €		
8		1000 €		
9		1000 €		
10		1000 €		
discounted sum	41683 €	7721,73 €		
	Co=	49404.73 €		
	ANFn,i=	0.129505	WGC (best case) =	2.87€/m³
	a=	6398.14 €/a	WGC * 2 (worst case) =	5.73€/m³

(D. Roncevic, personal communication, 26.11.2009)

The WGC for the BWPV-RO plant of the examples has been calculated with the annuity method. The plant has an investment cost of 41,683€. Moreover, every year 1000€ have to be paid by the operator for operation and maintenance. The plant has a daily capacity of 6.2m³/d. It is assumed that the plant is operating 360 days a year with full capacity. The adequate target rate is of 5% and the operational life span 10 years. With this data a water generation cost of 2.87€/m³ has been calculated. This is the best case. As explained in chapter 2 it is likely that the iwater generation cost is twice as high as stated by the company. In this calculation no transportation cost, installation costs or costs for a water storage tank are included into the calculation. The WGC for the worst case are therefore multiplied by two. In the worst and best case scenarios the investment cost have been reduced until the WGC are equal to the water price from the example.

Worst case

annuity method				
End of the year	Investment	maintenance		
0	5500 €		i = adequate target rate=	0.05
1		1000 €	Operation days=	360 d
2		1000 €	Daily capacity=	6.2 m³/d
3		1000 €	Annual capacity=	2232 m³/a
4		1000 €		
5		1000 €		
6		1000 €		
7		1000 €		
8		1000 €		
9		1000 €		
10		1000 €		
discounted sum	5500 €	7721.73 €		
	Co=	13221.73 €		
	ANFn,i=	0.129505	WGC=	0.77 €/m³
	a=	1712.28 €/a	WGC * 2=	1.53€/m³

Best case

annuity method				
End of the year	Investment	maintenance		
0	18700 €		i = adequate target rate=	0.05
1		1000 €	Operation days=	360 d
2		1000 €	Daily capacity=	6.2 m^3/d
3		1000 €	Annual capacity=	2232 m^3/a
4		1000 €		
5		1000 €		
6		1000 €		
7		1000 €		
8		1000 €		
9		1000 €		
10		1000 €		
discounted sum	18700 €	7721.73 €		
	Co=	26421.73 €		
	ANFn,i=	0.129505	WGC=	1.53 €/m^3
	a=	3421.74 €/a		