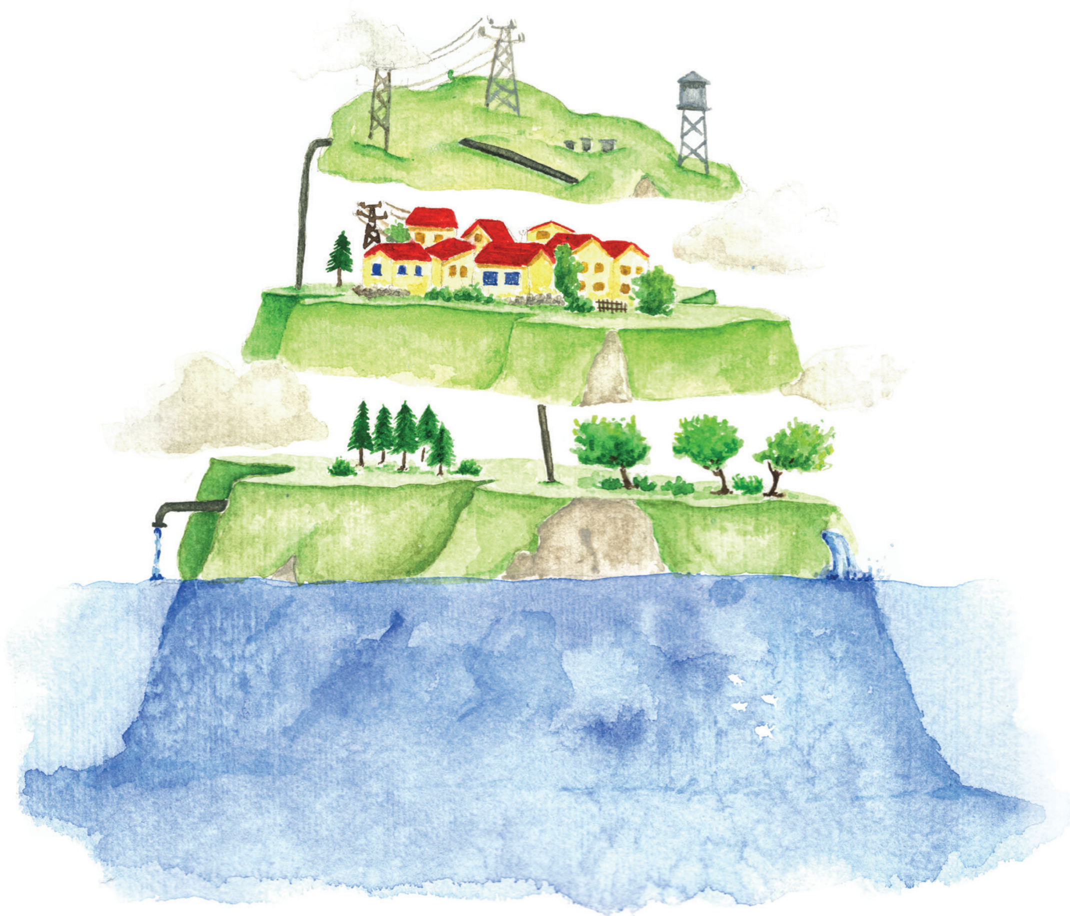
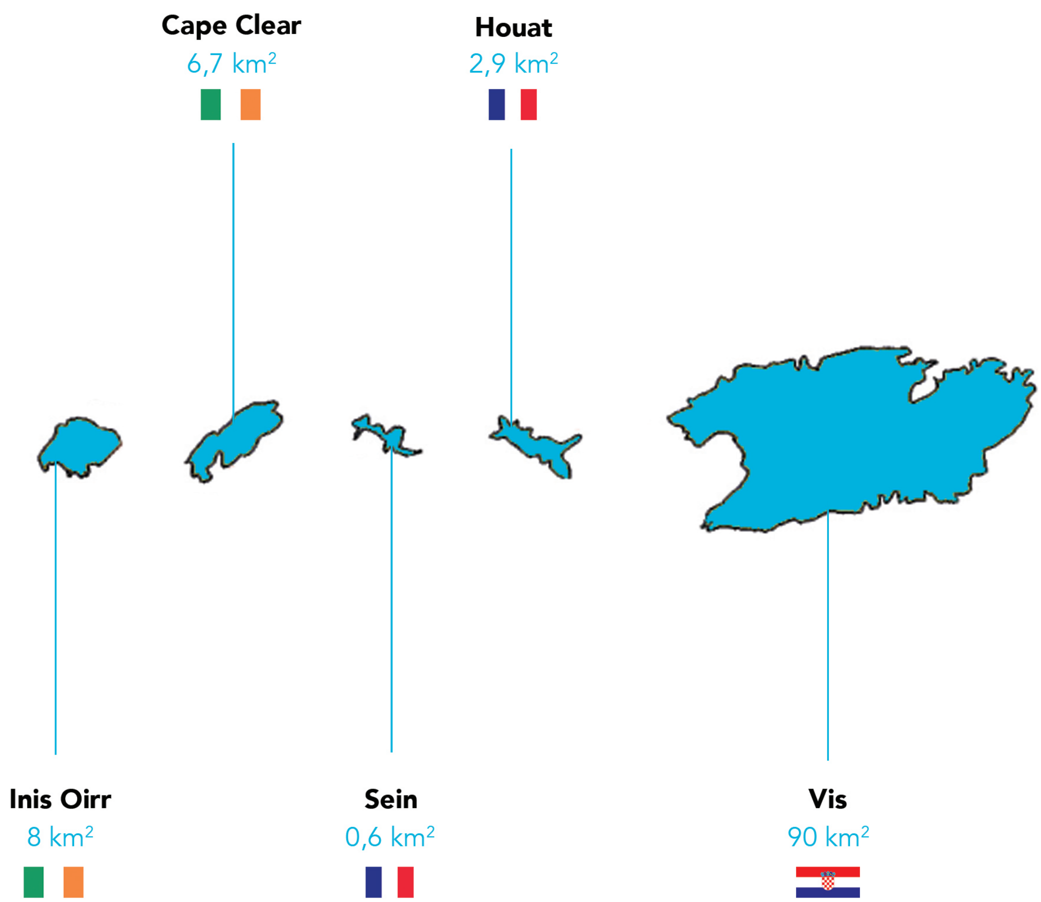
# WATER SAVING CHALLENGE

a smart guide to water management

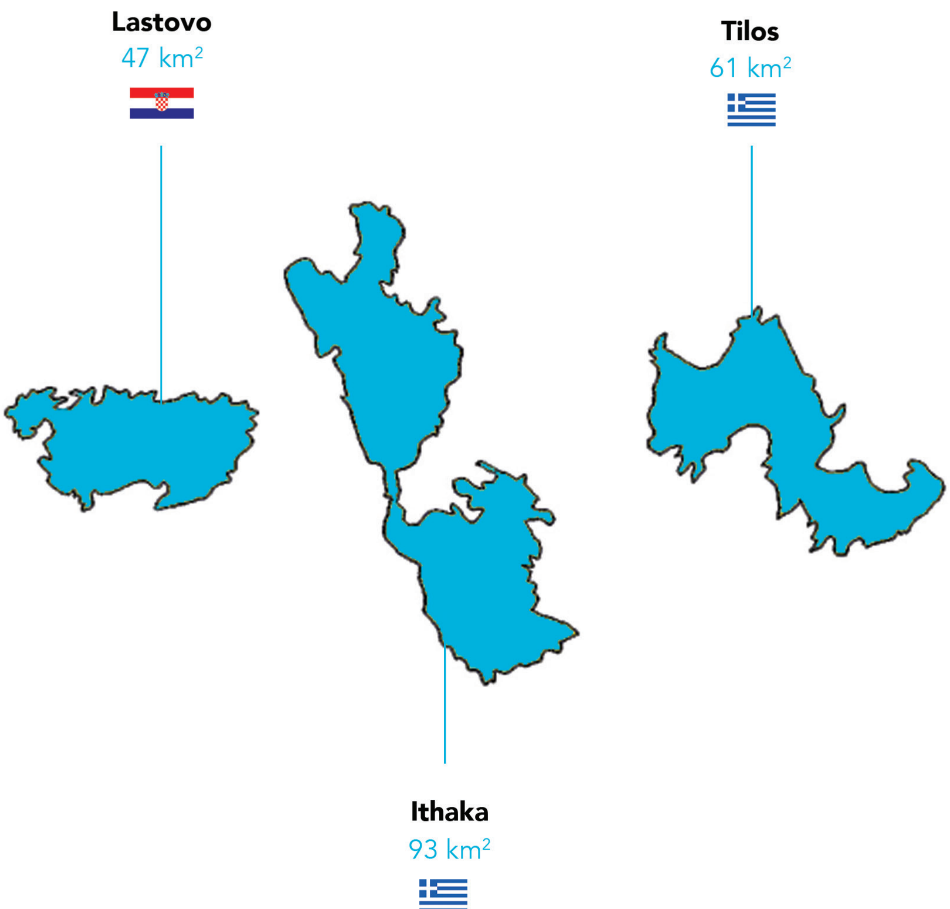


Group of the Progressive Alliance of
**Socialists & Democrats**
in the European Parliament

Office of **Tonino Picula,**
Member of the European parliament



Cape Clear
6,7 km²
Houat
2,9 km²
Inis Oirr
8 km²
Sein
0,6 km²
Vis
90 km²




***Map 1:*** *Map of the eight islands involved in the project*

## *Impressum*

| | |
|---|---|
| Publisher | Office of Tonino Picula, Member of the European Parliament (S&D) |
| For the publisher | Tonino Picula |
| Editors | Ivan Matić and Christian Pleijel |
| Text authors | Christian Pleijel and Anders Nordström |
| Design and illustrations | Iva Pezić |
| Proofreading | Virtualni asistent d.o.o. |
| Print | Kerschoffset d.o.o. |

This project is funded by The Progressive Alliance of Socialists and Democrats in the European Parliament (S&D)

TONINO PICULA
ZASTUPNIK U EUROPSKOM PARLAMENTU

www.toninopicula.com

## *Contents*

Dear readers,

I present to you this booklet with great pleasure. It is the result of a long-lasting cooperation of a great number of islanders and island devotees, of which I happen to be both.

As a born islander, I have always felt a special attachment to island communities. However, behind the much romanticized idea of island life, which most people are attracted to, my interest in islands has an additional dimension. Throughout history, despite the isolation, limited resources, high weather sensitivity and despite all odds, island communities existed and thrived. As a politician and a public servant, I find this both impressive and inspirational. Islands can indeed teach us a lot.

I therefore, without hesitation, began my cooperation with Mr Christian Pleijel from The Royal Institute of Technology in Stockholm on promoting the concept of smart islands and positioning them as sources of sustainable water saving solutions. In early 2017, together with representatives from eight European islands, we started exploring possibilities of using technology and human behaviour to save water based on the islands' vast experience. By trying to solve water shortages, many explore how to increase the water supply. We, however, focused on policies of decreasing the water demand – influencing the "other side" of the problem of water shortages.

Islands generally experience water shortages, and have accumulated skills for innovative solutions and models for mainland communities to follow through centuries. As an affluent

society, we tend to increasingly rely on solutions that deal with consequences, not causes. Mainstream solutions too often focus on how to supply more water to island communities through expensive infrastructural projects without regarding the environmental effects. Our project, and this booklet, aims at taking action at the other end of the water problem: aiming to rationalize the use of freshwater with mindful attention to the possible disadvantages such measures might have on people and businesses. It was this Water Saving Challenge project, focusing on water saving measures and putting islanders in the centre of solution creation, that was awarded the Greening the Islands Awards for 2017.

After a full year of field research and intensive teamwork, with a strong support of my Socialists and Democrats Group in the European Parliament, we are now able to present you with this booklet in form of a manual for all those who are interested in both theoretical and practical aspects of water saving solutions. Solutions displayed here are island solutions, developed and presented by remarkable islanders who dedicated their free time and expertise to this project. Experiences of the Croatian islands Lastovo and Vis, the French islands Houat and Sein, the Greek islands Ithaca and Tilos and the Irish islands Cape Cleer and Inis Oírr have all been instrumental in bringing this booklet to life.

The European policies towards islands are changing and for the better. With the establishment of the Intergroup on seas, rivers, islands and coastal areas in the European Parliament, islands got a strong and dedicated voice in the EU. Following the Resolution on the special situation of islands, the launch of the Smart Islands Initiative, as well as new funding made available for islands in the field of renewable energy usage, the future for European islands looks bright. The work, however, is far from over and I am determined to continue my work on behalf of islanders in the European Parliament.

The booklet in your hands is first and foremost a manual. It is a testament to island ingenuity we can all learn from. Regardless of whether you live on an island or not, I hope our work will help you see water issues in a new light and will encourage you to employ some, if not all, of the solutions islanders have shared with us. Let’s save water together!

Tonino Picula
Member of the European Parliament

## ***Acknowledgements***

This project would have been impossible without the initiative and guidance of Mr Christian Pleijel from the Royal Institute of Technology in Stockholm (KTH) and Professor Anders Nordström from the University of Stockholm. Their immense knowledge and expertise proved invaluable in brining European islanders together and shaping this water saving guide.

Great work is possible only with a great team. Mr Maxime Bredin (University of Brest, France), Mr Ivan Matić (Office of Tonino Picula, Croatia), Mr Mairtin O'Mealoid (island Inisheer, Ireland) and Mr Christoforos Perakis (Centre for Renewable Energy Sources and Saving - CRES, Greece) made a great core team coordinating multinational cooperation and national research work.

In coming up with solutions and models, the time, knowledge and dedication of the following islanders proved exceptional: Ms Tonka Ivčević (mayor of Komiža, Croatia), Ms Maria Kamma (mayour of Tilos, Greece), Mr Leo Katić (mayor of Lastovo, Croatia), Mr Daniel Salvert (mayor of Sein, France), Mr Dionios Stanitsas (mayor of Ithaka, Greece), Mr Ambroise Menou (Councillor of Sein, France), Ms Andrée Vielvoye (mayor of Houat, France), Mr Denis Barić (Otočni Sabor, Croatia), Mr Josh Becerra (Fluid Water Meter, USA), Ms Sara Borgström (KTH, Sweden), Mr Olivier Brunner (Agence de l'eau Loire-Bretagne, France), Mr Padraigh Crowe and Ms Cathy Ní Ghóill (Irish islands co-op), Mr Julien Fizet (WiCi Concept, France), Mr Ronan le Goaster (Syndicat Departemental de l'Eau de Morbihan, France), Mr Gerry Hynes (Renergise Ltd, Ireland), Ms Maja Jurišić and Mr Andrijano Nigoević (Island Movement, Croatia), Mr Elefterios Kechagioglou (Hellenic Small Islands Network, Greece), Mr Slaven Kevo (Vis, Croatia), Ms Eleni Palaiolougka (CRES, Greece), Mr Lučijano Sangaleti (Lastovo Utility Company, Croatia), Mr Michael Schembri (Energy & Water Agency, Malta), and Mr Vassilis Simiris (Ithaka Water Management, Greece). The thousand islands of the European Small Islands Federation (ESIN) has been a great source of reliable, down-to-earth island knowledge.

A special thanks is due to Professor Louis Brigand from Université de Bretagne Occidentale, Mr Denis Bredin from the Association Iles du Ponant, and Professor Andy Backer from the University of Bilbao, whose comments on working materials made the work easier and this guide better.

In late 2017, we were awarded the "Greening the Islands" award which encouraged us to keep up the good work, as did the support of media who devotedly followed and promoted us.

Finally, special thanks go to the island communities of Lastovo and Vis (Croatia), Houat and Sein (France), Ithaka and Tilos (Greece), Cape Clear and Inis Oírr (Ireland) for providing an incredible inspiration and proving islands can indeed lead the way.

# Introduction

## *Thinking inside the box*

Islands are pretty little buttons on the big European coat. Although surrounded by vast volumes of water, their freshwater sources are often scarce. Having many tourists, islands need large amounts of fresh water, especially in summer when demand peaks sharply. Islands may become unattractive because of water shortage.
To avoid their running dry, we are thinking outside the box. We dig deeper, install larger desalination plants, invest in underwater pipelines to the mainland and/or import fresh water by barges. We assume risk in order to make islands independent.

Why not think inside the box? What if there are solutions within the frame? What if we don't need as much water as we produce? What if a lot of water is lost due to leaks, bad technology, unreasonable behaviour, unwise governance and inadequate pricing systems? An island has distinct borders. It has a shoreline which makes it a well defined piece of land, a place suitable for thinking inside the box and making changes within the system. Saving water on an island is feasible, and can be done transparently for lesser costs and improved sustainability.

## *The challenge*

Islands are closed systems where you can devise and develop local, integrated solutions. We believe most islands can save about 25 percent of the water used. During 2017, a group of eight European islands focused on water saving. Some of them – like Ithaka and Inis Oírr – were forced to turn off the water on certain days of the week, or at night. These islands actually tried and discovered it is possible to cut their freshwater consumption by 10 to 55 percent.
To sum up, the amount of water saved per year

on these eight islands with a total resident population of less than 8,000 people was 200 million litres, which also saves 470,000 kWh and 42,000 kg of $CO_2$ emissions.
Should this knowledge be transferred to the 2,136 islands of Europe and their 18.9 million inhabitants, life on the islands would become easier, more secure and much more attractive.

*See Map 1 of all eight islands on the inside of the front cover and the Map 5 of their geographical position on the inside of the end over*

## *Can any island save water?*

Islands can serve as small-scale laboratories, where creative water management practices can be tested under safe, well-defined, conditions. The human pressure on the islands changes with the season and fresh water can be scarce, especially when the population peaks. Whilst a mainland European uses 128 litres of fresh water a day (or even more, when vacationing on an island), islanders have learnt to use only half of that amount. It is not that we islanders are dirtier than the rest of you, it is just everyday, simple water slimming: being aware of our behaviour, using smart technology, and managing the island water system in a wise way.

## *How to go about it*

Saving water is not about writing a plan on paper. It is about achieving common knowledge, creating common understanding and undertaking common actions. There are many actors involved: politicians, businesspersons, political organisations, civil servants, extraordinary people and even visitors.
Important causes call for important projects. It all starts with a cause – a challenge.
You will then need to gather a team in order to create a shared mental model of what is possible to attain.
With your team, you have to study your own island. To get a comprehensive overview of the freshwater situation, all of the island must be observed: it is not enough to describe the wells, mains, cisterns, pumps and pipes, but you must also figure out how it is processed, how it reaches the consumers, what it is used for, how the water system is managed and how the water is priced.
To make an intelligible model out of all these facts, we invite you to cut your island into three overlaying, horizontal slices: the first slice is *the water of the island* which is the physical landscape, the second is *the water of the islanders* which is the cultural landscape and the third is *the water of the community* which is the technical landscape.

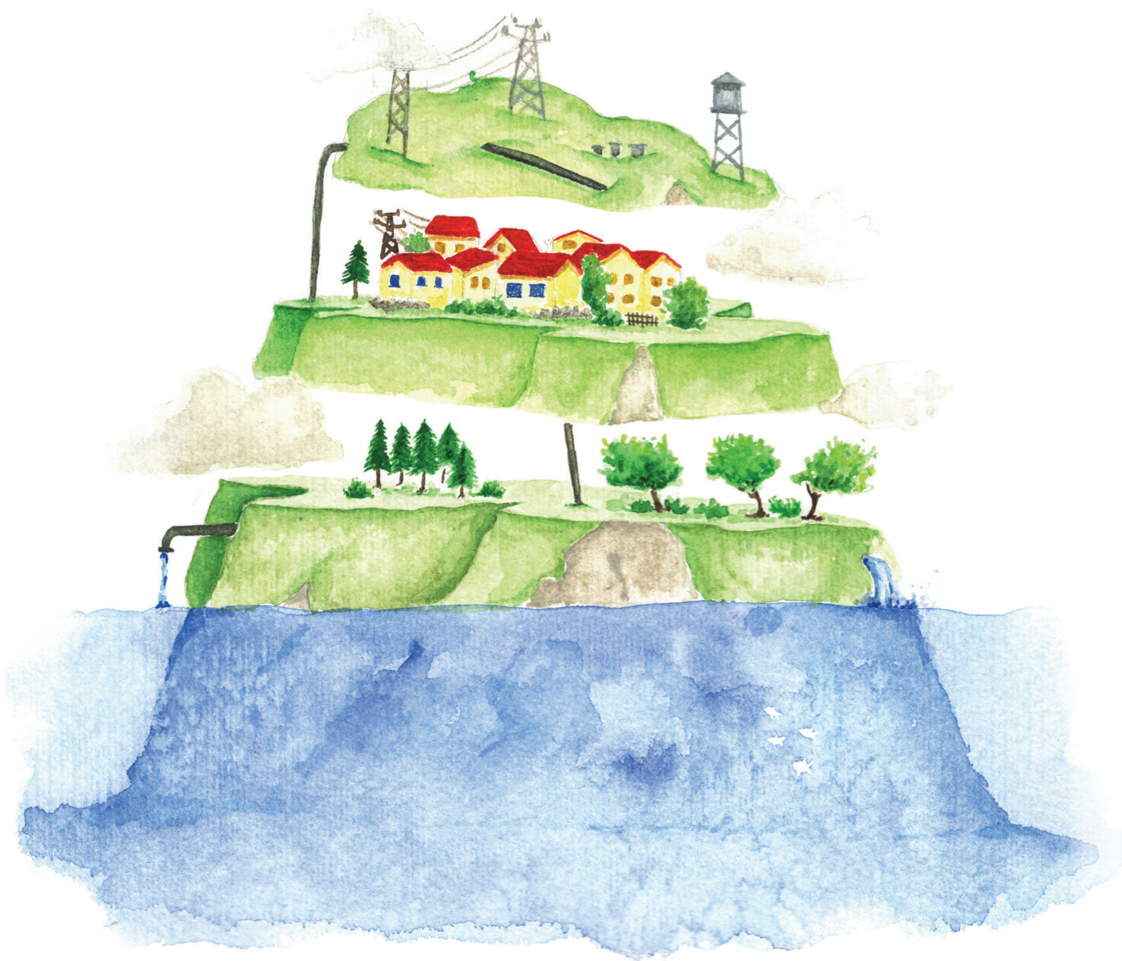


***Illustration 1**: The three layers of an island*

## *The water of the island*

This is the basic hydrogeological system level which includes the physical geographical conditions on your island – it does not matter if people live there or not: the surrounding sea, the bedrock, the weather conditions (especially rainfall) and the island's ability to contain water. This is the basic slab, the physical bottom of the island, the groundwater and rainwater systems of your island. This is the part where you describe your island's water assets.

## *The water of the islanders*

We, humans, move in, imposing our culture upon one of Mother Nature's most delicate children: an island. We leave our footprints everywhere, we build houses and villages, till the soil, extract water, eat, drink, work and sing. We arrange our lives with children, schools, health care and security, using water in many ways for various purposes. We create a cultural, human landscape on top of the natural landscape. This is the part where you describe the water needs of your island.

## *The water of the community*

On top of the physical and the cultural slices, we create an infrastructure of drills, mains, pipes, roads, ports, ships, waterways, fences, wires, fibres and so forth, to make it possible to communicate, move around, have light and heat, produce energy, food and water. One such infrastructure are today's water schemes which have replaced yesterday's springs, lakes, private wells and rainwater harvesting. This is the technical landscape which ends with a consumer having water by just opening a tap or flushing the toilet. This is the part where you describe how this common system is configured and financed.

Gathering all these facts is part of making a water saving plan. If you want change to happen, it is important for everyone to be on the same page, to find common ground, before setting goals and discussing actions. You need to show each other what has been done and discuss what you want. You need to share ideas and come up with new ideas – inside the box.

When making the plan, we propose using Edward de Bono's simple and creative method called *Six Thinking Hats* combined with Ishikawa cause/effect diagrams and Metaplan group facilitating techniques.

After that, you can move onto broader action. Change started the day you first defined your challenge, now you will have to disturb the social, technical, economic and political systems of your island. Water saving calls for bold, long-term strategies including simultaneous changes in (residents' and tourists') behaviour, investments in infrastructure, and brave politicians.

There must be quick wins providing emotional reward to everyone in the project, and keeping critics at bay, but you will also have to attack the sturdy defences and difficult politics of the old system.

Change is fragile. If you have wisely balanced the three types of actions – changing people's behaviour, engineering, and wise governance – in a consecutive seven-step process as described in chapter four, chances are that change will stick. Your changes will have roots.

### *Can you do it?*

In this book, you will find five short lectures:

| | |
|---|---|
| *Lecture 1*<br>**The water of the island** | This first lecture is about how to understand and describe the water resources of the island. Its purpose is to help you grasp the situation on your own island. |
| *Lecture 2*<br>**The water of the islanders** | The second lecture shows how to calculate, understand and dispute the water needs of the islanders, and to do it for your home island. |
| *Lecture 3*<br>**The water of the community** | The third lecture deals with the design and development of the common infrastructure for providing fresh water to the island community. |
| *Lecture 4*<br>**The water we can save** | The forth lecture describes how water can be saved by smart information, by clever technology, and by wise governance. |
| *Lecture 5*<br>**The water saving challenge** | The fifth lecture proposes a seven-step process, how to go design a water saving project. |

Interlaced in the text are ten excursions to islands (lectures 1-3) and twenty-six examples on how to save water (lectures 4-5).
Following each of the first three lectures is an exercise that helps you practice what we are preaching. It will help you get an overview of the water conditions of your island, like a dashboard in a car telling you how much fuel you have, how much fuel you are consuming, and if your engine is running hot. The exercises will help you know how much water you have, how much you are using, and whether the system is running dry.
There is a website (*watersavingislands.eu*) presenting more information, links, templates and details on fighting water waste.
This is not a very theoretical book, but it contains enough theory to make everyone understand what should be done, and enough practical guidance to get it done. Let us be your learning butler.

Can you save water?
Of course you can.

# The water of the island

This lecture is about how to understand, describe and respect the water resources of the island. Its purpose is to help you describe the situation on your own island. We use examples from the eight islands in our study to translate theory into understandable language.
Water is a very simple chemical compound – $H_2O$ - with a wide variety of special properties. It appears in various forms such as ice, water or vapour. One of the most important features of water is its extremely good solubility. Therefore, water can even break down minerals and rocks.
We – people, plants and animals – can't do without it. An organism typically consists of 65-90 % water. We use it as a solvent and a carrier for nutrients, excretion products, oxygen and carbon dioxide. We use it in households and industry, on farms for animal husbandry and crop irrigation, but also for hydropower, shipping, fishing, recreation as well as a receiver of contaminants.

## *Global water resources*

Fresh water is a very limited resource: the oceans surrounding our islands make up for 97.5 % of Earth's total water volume. This seawater is saline. Fresh water represents only 2.5 % of the total water on Earth.
Looking closer at these 2.5%, most of it is bound in glaciers and ice caps. Groundwater and surface water constitutes 1%. Much of the groundwater is located at large depths deep below the ground. It may be difficult to exploit, technically and economically, it can sometimes be saline, but it is our most import-

ant freshwater magazine. Surface water seems to be easier to use but is often under legal protection and may often be contaminated by agriculture, various industries and households. Freshwater is a scarce and fragile resource we depend on, but too often take for granted.

## *The water cycle*

All water on Earth is part of a cycle. We only have a given amount of water, it remains the same while moving continuously in a closed system. Little drops of water make the mighty oceans and the water we drink today may contain water molecules from a bath Cleopatra took 2.000 years ago.
As the sun shines, water evaporates from seas and lakes, and transpires from all organisms. Winds blow the water vapour up and away into the atmosphere, where the water molecules become so large that drops start falling as precipitation (rain, hail, snow, mist and fog). Most of the rain reaches the ground, infiltrating the soil or the bedrock via cavities and fractures, and watering plants.

## *Groundwater recharge*

The rainwater trickles and oozes down to the bedrock – we call it percolation. Eventually, the water reaches an area which, due to small fractures, slows down the percolation of water. The pores in the soil layer closest to the rock surface can then be filled up to 100 % with water. When all pores and fractures are filled with water, we call it groundwater, and the upper level that limits this groundwater-filled area is the groundwater surface.
The bedrock of an island can be sedimentary rocks that have both pores and fractures, or it can be rocks without pores but with smaller or larger fractures/cracks.

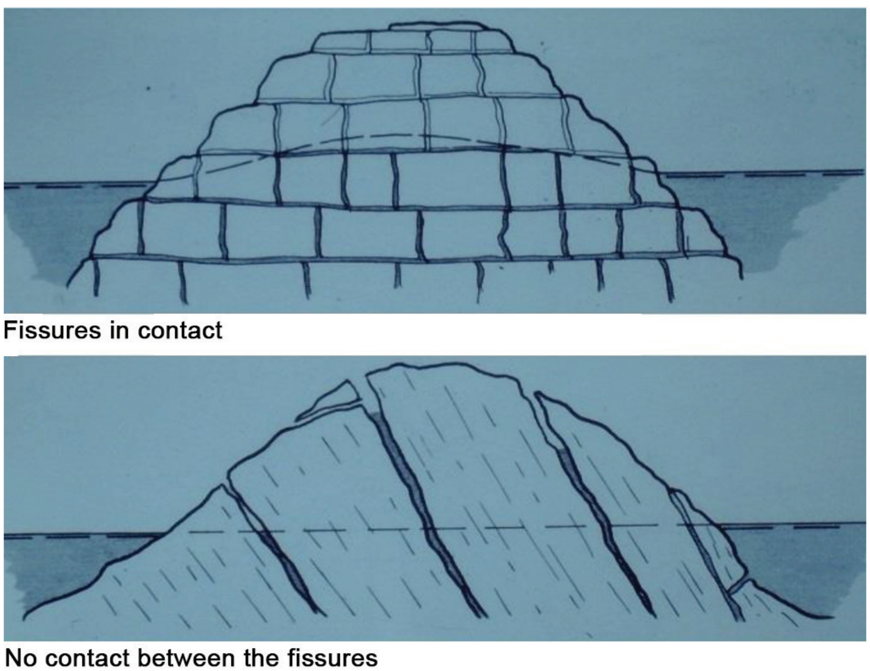
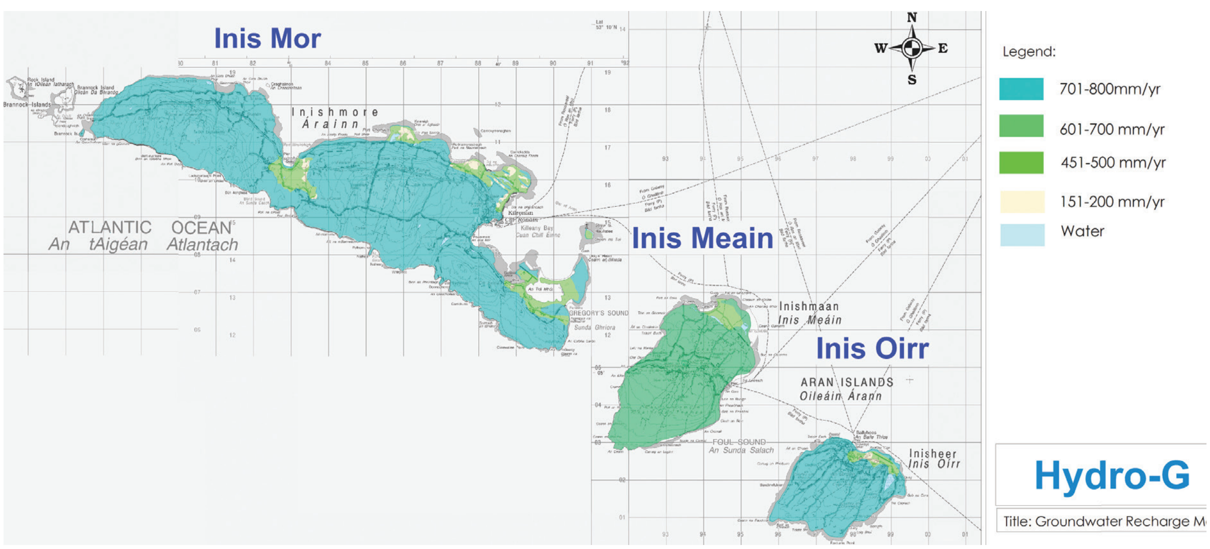



***Illustration 2:*** *Groundwater in bedrock*

Limestone and sandstone are sediment rocks formed as deposits in rivers, lakes or ocean bays (such as calcareous clay or sand), and their pores result from their formation as sediment. After millions of years, sediments became rocks. Limestone has been chemically affected so that the lime has been dissolved and removed from the rock, with larger pores, sometimes even large cavities or caves. Limestone islands such as Inis Oírr can keep large amounts of water in their large pores, while bedrocks with only fractures like Houat have smaller groundwater magazines.

### Excursion 1

**Inis Oírr** (English: Inisheer) is the smallest, innermost of the three Aran islands on Ireland's Western Coast. These islands are limestones interbedded with layers of shales which were laid down when the sea receded. Doctor Andrea Bartley explains what happened then: "The soil cover was removed by glacial activity exposing bare limestone. The bedrock surface has been weathered by the elements. This has resulted in the rock surface being fissured where it has been exposed. These fissures are generally shallow being less than 3 meters in depth. These fissures have been developed by rainwater. The rain that falls on the island runs down these fissures until it meets a more impermeable layer which usually takes the form of a thin shale band. The water then runs laterally along this stratum until it reaches the sea."
The area of Inis Oírr is 8 $km^2$. It has an average yearly rainfall of 1,153 mm. Yearly groundwater recharge can be calculated as rainfall from October to March x 0.8 = 461 mm.




***Map 2:** Rainfall on the Aran Islands, Ireland. Take special note of Inis Oirr.*

## ***Water from lakes and streams – surface water***

The groundwater moves with the force of gravity, travelling deep and laterally, flowing from heights to the valleys where groundwater outflows are formed which we call springs that can form a stream, flow out to the sea around the island, or into a lake. A lake has an outlet, a river flowing to the sea. We call all stream water and lake water surface water. On smaller islands, it is uncommon to find permanent flowing streams, and lakes are rare on islands in general. Islands made up of limestone usually have a rapid groundwater flow to the sea. If limestone rocks reach the coast, groundwater often flows out in springs in the coast cliffs. Sometimes these springs only exist during the rainy period (typically winter).

When the rains cease, the groundwater surface drops and the groundwater pressure in the soil or bedrock decreases, resulting in less water flowing out of the springs, and eventually no water flow at all. When new rain falls and the water magazine is refilled, new groundwater is formed, pressure increases, and water starts flowing from the spring again.

Places where groundwater flows out are usually below the surface of a lake, stream or even below the seabed on islands. This outflow is invisible but can be very large. The amount of groundwater flowing out to streams, lakes and seas equals the groundwater recharge or all rain minus vegetation transpiration.

In low-lying terrain, the groundwater surface may be at or very close to the ground surface, creating a wetland. In this part of the terrain no water moves downward, only laterally along the ground surface.

On an island, it is usually easier to see groundwater flowing to the coasts, especially when the coast consists of mountains. From the mountain side, groundwater flows from frac-

### Excursion 2

**Tilos** is a solitary limestone rock rising 600 meters above sea level in the Aegean Sea, which is about 500 meters deep around the island. It is one of the islands of the Dodecanese, located 22 nautical miles (2-3 hours) NW of Rhodes and 222 nautical miles (15 hours) from Piraeus. The area of the island is 61.5 $km^2$.

Walking on the island's beautiful stone-paved tracks, passing settlements, dovecots, chapels, springs, stone bridges, small rushing watercourses, watermills, threshing circles and olive presses among holly oak, mastic and oleander trees, you can understand how the hydrological conditions of Tilos are a result of its climate, the karst limestone relief, the steep slopes, the fragmentation into many small or larger drainage basins, and the absence of vegetation on the mountain sides.

tures or cavities. The outflow occurs mostly during the rainy periods. Part of the year the outflow is small or simply does not exist. Do remember that most part of the outflow is invisible below sea level. Even groundwater formed in the middle of the island is transported to the sea by gravity even though it can take a long time.

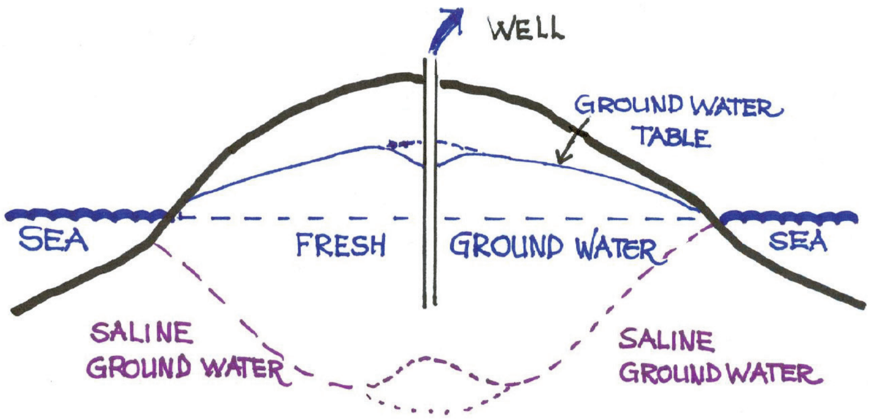
## *Green water*

If it hasn't rained for a long time, the plants' roots have used up all the water in the upper parts of the soil and the soil runs dry. When the first rain falls on the surface of dehydrated soil, it will be bound to the surface of the soil particles as a very thin film (hygroscopic or bound water). The force with which water molecules adhere to the particles is so strong that the plants' roots cannot absorb this water. It will eventually be lost through evaporation to the atmosphere if the particles are close to the ground surface.
When more rain falls and water is infiltrated, the water percolates to the cavities between the soil particles. It is the capillary tension that holds the water in the pores. It can be described as several molecules of water held together by the electrical forces of the molecules (oxygen and hydrogen ions). The smaller the pores, the easier the capillary tension can hold enough water in the pore to fill it, partially or completely. This is especially true for soils with clay and silt. If the pores are larger – as they are in sand or gravel – the pores can only partly retain capillary water, while the rest is filled with air and other gases from the plants' roots.
Plants use capillary water in the pores. Through the roots' sucking ability, the water is raised to the plant's parts above the ground surface wherefrom the transpiration of the plant occurs.
What we call green water is the part of the rainwater that is retained in the soil. It is the "water reservoir" of the plants and it provides at least 70 % of the freshwater used for cultivating food in the world through rain-fed agriculture. When the green water reservoir cannot hold more water, the water starts percolating to the area below the plants' roots.

## *The challenge of fresh and saline groundwater*

As fresh groundwater is lighter than saline water from the sea, an island's fresh groundwater is a floating cushion above the deeper situated saline water. In between the fresh and saline water, a mixed zone of brackish groundwater is formed. The level of this brackish zone depends of groundwater recharge and discharge, defined by the transportation speed of the groundwater that, by the force of gravity, moves out to the sea.
For fresh groundwater to be used as potable water, recharge and discharge must be in balance. When pumping fresh groundwater with a tube well, we make the discharge greater than the recharge. The groundwater level will sink, the freshwater cushion will be-

come lighter and the brackish zone will move upwards. Caused by the physical difference of fresh and saline water the up-movement is greater than groundwater level depression.
We risk getting brackish or saline groundwater in our tube well. Summertime, with huge needs of potable water, when rain is rare and no groundwater recharge exists, is an extremely dangerous time to get the discharge of fresh groundwater unbalanced.
The best source of potable water is always fresh groundwater – both due to its quality and its costs.




***Cross section 1:***
*Sustainable well usage*

## Excursion 3

**Houat** (*Enez Houad* in Breton) is a French island in the Atlantic Ocean, off the south coast of Brittany. It is a massive of gneiss and granite in a mild slope, 5 km long and 1.5 km at its widest point. There are sand dunes in the northeast and the southeast, the rest of the coast is from 14 to 29 meters steep, cut by ravines with sandy beaches. Inside the islands, the terrain is mostly flat (25 to 28 meters).
The surface of Houat is 2.9 $km^2$. Since the average rainfall is 910 mm per year, that means that a total of 750,000 $m^3$ rainwater falls on the island per year. Groundwater recharge is about 480 mm in most parts of the island, the visible runoff from the mountain sides into the sea is about 220 mm and the rest of the groundwater runoff is submarine. The thin soil cover on a large part of the island's surface, as well as the bedrock's thin cracks, hampers infiltration in the bedrock.
Groundwater is the source of Houat's overall water used for consumption, although very deep wells sometimes cause saltwater penetration. The bedrock has cracks of various sizes and amounts, allowing for a wide variety of possibilities for outlets across the island.

### What about climate change?

Islands will face climate changes over the next decades and beyond, until the end of this century. Scientists make scenarios of rain and temperatures across different geographical areas, and it seems both extreme rain (very heavy rain in a short time causing floods) and extreme dry periods will become more common. Displacements of the rain periods throughout the year may occur but with significant variations over the years. Temperature and rain changes will affect the vegetation periods, and longer vegetation periods mean greater transpiration from plants and less groundwater recharge with declining groundwater levels.

## EXERCISE A – The water of your island

Now, it is you turn. Remember how we used a dashboard as a metaphor? It would be nice to have something as simple as a fuel gauge in a car to monitor the water assets of your island. Although the water system is a bit more complicated, you can map out the water resources of your island with four sets of actions: (1) finding data on the precipitation, (2) searching for someone who can describe the hydrogeology, (3) making field research, and (4) understanding how climate change might affect you.

### 1 – PRECIPITATION

Which is the nearest meteorological station? Can you get accurate data from it? How much does it rain from month to month? What is the average yearly rainfall in mm? A simple rule is that 80% of the rain during the period from October to March creates groundwater. What is the average temperature in winter and in summer?

### 2 – GROUNDWATER FORMATION

Has there previously been an academic hydrogeological research done on your island (it doesn't have to be recent – hydrogeology doesn't change on a daily basis)?
Are there any technical reports from consultants searching for water?
Can you extract a simple, non-academic, understandable description of your island's hydrogelogical situation?

### *3– FIELD RESEARCH*

Make a map of natural water resources such as springs, streams, ponds and lakes on your island. Map all public and private wells.
Visit the natural water sources of your island with someone who can tell you about water quality, the amount/flow of water, and what it is used for.
Meet with people who have private wells and rainwater reservoirs. There can be important local knowledge on water. Quality? Flow? Salinity? Make interviews with farmers and tourism entrepreneurs.
Get a good overview of the local water scheme: where does it get its raw water from, how is it processed, how and where is it stored, how is it distributed, how much does it cost the community and how much do the consumers pay? Are there any major problems, is there salt-water intrusion? What about leaks?
Do explain the purpose of your questions. Being over-curious, you might frighten people and officials. In the end, we just want to make better use of the water resources we have.
Always take notes and photos when on field trips, indicate places exactly on a map.

### *4 – CLIMATE CHANGE*

How does/will climate change affect your island? Have these risks been accurately described in a reliable way? Are these risks accepted – even included in long-term plans?

Having answered these four sets of questions, you are well prepared to move on. You have a good understanding of your water resources. Let’s turn to next page to see what demand there is for water.

# The water of the islanders

This lecture is about how to understand, calculate and dispute the water needs of the islanders.

Roughly 2/3 of all water on Earth are used for irrigation in agriculture. Industries use large amounts of water for cooling, they need boiler make-up water, and industrial process water in pulp and paper, chemical, petrochemical, coal and cement industries. Islands in general have undergone big changes. Residents are not so numerous, but visitors are. On many islands, agriculture has declined in favour of tourism, which is the new industry of the islands. Canneries have closed, shipyards are few, fishing has decreased significantly and manufacturing was never important. To understand modern water use on an island, we need to have a look at households, industry, agriculture and tourism.

***Photo 1**: Greek woman with a glass of precious water*

## *Household use*

We don't consume water, we just use it in different ways. Water is essential for life but the amount of drinking water required by a human varies. It depends on physical activity, age, health issues, and environmental conditions. As a general rule, the human body needs about two litres of water per day to compensate for urine drainage and transpiration from the body. Most of the two litres are acquired by drinking, but some fluid is supplied to the body via the food we eat.

During a meeting in the European Parliament at the beginning of our project, Mairtin O´Méaloíd from the Irish team vividly illustrated how we drink a small bottle of water to quench our thirst and then use 10 litres of water to flush the toilet after urination.

The use of water in the household, daily hygiene, use of the toilet, dishing, dishwasher and laundry, cleaning, watering of flowers indoors etc. constitutes 75-150 litres per person per day (l/p, d). If there is a garden, water use can be even higher. Depending on the type of accommodation, water can also be used for other purposes (washing the car, a pool etc.). These other usages usually require between 75 and 150 l/p, d.

Water use in the household (per person) doesn't only depend on what we need but also on technology, pricing and management of the production and distribution systems.

Nevertheless, water use for hygiene has increased sharply in many European countries over the past 50 years. This is partly due to the availability of hot water, and the creation of a subsequent culture in which you often take more than one shower per day and change clothes much more often than before.

Measuring water use in a house or an apartment to record different types of water usage is not easy, and it is not a priority research area for authorities or universities. In areas where water shortage occurs periodically or suddenly, there are reasons for the municipality to conduct investigations that can lead to a common water saving awareness among residents and visitors.

Water for the household – related to accommodation – may be municipally distributed water, groundwater coming from a well, drilling or fountain, or water from lakes and streams (which is rather unusual on islands). Historically, rainwater was used to a greater or lesser extent.

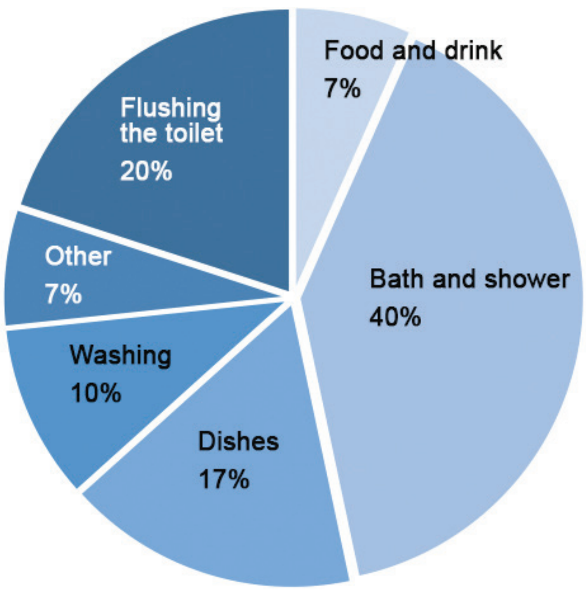



***Diagram 1**: Average household water use distribution*

## *Industry*

An island has industries that also use water: restaurants, hotels, laundry facilities, and the municipality's waterworks that produce clean drinking water are only some examples of common activities. Small-scale industrial activities on islands, such as fishing industry and shipyards, are another kind of water users. The same goes for schools and offices, shops, hospitals or healthcare services, small craft businesses and sports facilities.

## *Agriculture*

Agriculture with cultivation and animal husbandry often requires large amounts of water. Not 'manufactured' water, but still freshwater from the same reserves as we use. A cow needs from 10 to 100 litres per day depending on age, body size (weight), stage of production, and the environment. Lactating cows drink nearly twice as much water compared to dry cows. The same applies to goats who need 4-5 litres of water per day and up to 10 litres per day when lactating, and who refuse to drink dirty or contaminated water. Sheep: a weaner needs 2-4 l/p, d, whereas an adult sheep needs 2-6 litres if grazing on grassland, 4-12 litres on saltbush.
It takes 995 days to grow cattle. Globally, the "food animal" population equates about 2.85 animals per human, which might also apply to islands.

### Excursion 4

**Inis Oirr**, which we visited in the first chapter. As the island, a barren rocky outcrop, originally had very little soil, the islanders created soil – using sand and seaweed. They sheltered the crops by building stonewalls, dividing the land among them. The result of their labour is evident in an amazing myriad of stonewalls with a total length of 360km.
Counting humans, the island has a resident population of 260, some 400 summer residents in 100 houses, 130 students during 3 x 3-week courses, 100,000 day-trippers and 50,000 weekenders (who typically stay 3 days). To make a living, residents work in tourism, as seamen, in social services and in farming. The tourism season is long, from March to November. There is a post office, a summer college, a church, a community centre, a hotel, a hostel, eight B&B's, two self-catering facilities, one healthcare centre, one café and two bars/restaurants.
The island needs about 40 million litres (40,000 $m^3$) of freshwater per year. The pressure on the water scheme is very uneven, peaking in summer.

## *Tourism*

Visitors make up important segments of water use on islands. One segment consists of summer residents, staying a large part of the year in their own properties on the island. They use the same amount of water per person and per day as the permanent residents on the island do. Another segment are those who stay for a number of days in rented houses or apartments and have more lavish water habits. The third segment is made up of day-trippers, who are only on the island for a part of the day. They use water from restaurants, campsites, bathing places and public toilets. The fourth segment are visitors who come by their own boats to the islands. These visitors have different water habits: a day-tripper uses 20 l/p, d, while a 5-star hotel guest uses 400 l/p, d.

Although visitors and part-time residents use water only for a short period of the year, their numbers drive a large-scale need for water in the summertime which might exceed the municipality's capacity of producing water. This leads to water shortages affecting residents, visitors and the tourist business who can lose customers, short-term or long-term, if the guests decide to shorten their stay on the island.

### Excursion 5

Going back to **Tilos**, where people have been living for 10,000 years, maybe along with the island's famous dwarf elephants. Minoans, Mycenaeans, Dorians, Sicilians, Egyptians, Romans, crusaders, Ottomans, Italians and Germans had ruled over Tilos until it joined Greece in 1948, together with all the Dodecanese islands. After that, population rapidly declined as many Tilians emigrated to USA or Australia. There has been a recovery since year 2000 due to the improvement of the island's sea connection to Rhodes and an improvement in tourism, which is now the main source of income for the majority of the islanders.

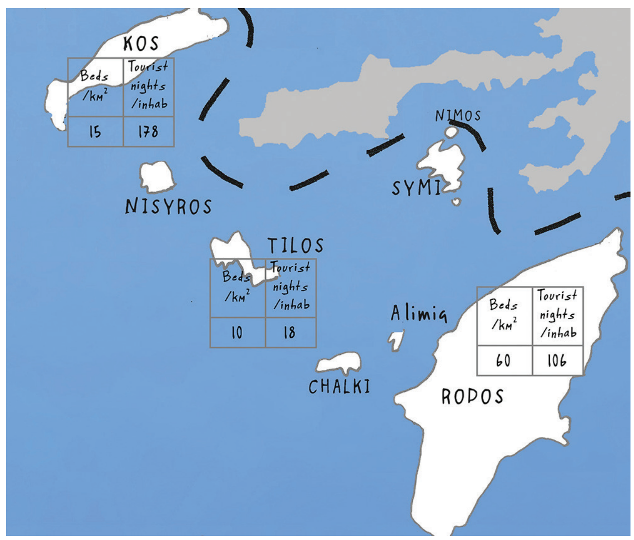
Today, there are 600 permanent residents on Tilos, whereas there are approximately 500 seasonal residents – people who, although they have a residence, stay on the island only a few months a year. In addition, the island has a capacity of approximately 1,300 beds (hotels, rooms, etc.), while there are two free camping sites on the beaches of Eristos and Plaka, peaking during the summer season with 500 campers.

Let us recalculate these people into person-days:

| | Spring | Summer | Autumn | Winter | |
|---|---|---|---|---|---|
| Residents | 600 | 600 | 600 | 600 | 216.000 person-days |
| Seasonal residents | 0 | 175 | 475 | 150 | 72.000 person-days |
| Tourists | 0 | 390 | 1.105 | 325 | 163.800 person-days |
| Campers | 0 | 0 | 450 | 0 | 40.500 person-days |
| **Sum** | | | | | **492.300 person-days** |

The total number of person-days per year on Tilos is 492,300 - almost half a million. Dividing 492,300 by 365, we get an equivalent of a population counting 1,349 permanent residents. This is what we call the "technical population", a number which describes the human pressure on Tilos' healthcare, mobile-phone, rescue, fire prevention, waste, sewage, energy, transport and water supply systems more accurately than the census figure.

Water consumption in Tilos is 54,000 $m^3$ as measured by water meters installed at the final consumers of the water supply network and recorded every three months of the year. There are some small supplies that are not recorded, because they are not priced, as in churches, schools and municipal buildings. There are also 5-6 private boreholes for irrigation purposes with small (~5 $m^3$/day) supplies that are not recorded.




***Map 3:** Number of hotel beds, here on Tilos, Rhodos and Kos, is an indicator of human pressure and the need for water*

This fits well with a cross-check calculation of person-days with the average 125 l/p, d consumption in Greece:

| Category | Person-days | l/p, d | **Total** |
|---|---|---|---|
| Residents (365 days) | 216.000 | 125 | **27.000 m³** |
| Seasonal residents (90 days) | 72.000 | 125 | **9.000 m³** |
| Visitors | 163.800 | 100 | **16.380 m³** |
| Campers | 40.500 | 40 | **1.620 m³** |
| **Total water use** | | | **54.000 m³** |

Of these 54 million litres of water, only 4 million (7%) is for drinking, over 21 million litres is for showers and over 10 million litres is used to flush toilets.

## *Wasted water*

Wasted water – not wastewater – is water used without intention and benefit. This is caused by mismanagement and leaks.
Water use is partly a function of how water is priced. If the energy price for heating water increases, it can cause a reduction in water use. On the other hand, the cost of water for most European households is far too low to motivate important water-savings. There are only a few examples of our islands where the water price is used to calibrate water use.
Water use also depends on the amount of leakage in the water production and distribution systems – an unwanted and large part of municipal water use. There are examples when leaks represent more than 60% of the total water production in the municipality. The normal value would be about 20%, including the water processed in freshwater production. If one excludes the waterworks purification water, leakage on average in one year should not exceed 15% of the total production.
Leakage typically derives from old water mains and pipes, where smaller corrosion holes in the water pipe or leaky joints are not visible above the ground surface and are also difficult to track, although there is sound measuring equipment for detecting the location of small-

er water leaks. Larger water leaks create pressure drops in the water distribution so that the water cannot reach the taps of the consumers. This is first visible in the apartments situated higher up. Large leaks usually create a hole in the ground and water flows onto the ground surface. Unfortunately, most municipalities are not actively trying to track leaks.

### Excursion 6

**Sein** is an island outside the coast of Brittany, France. On average, the island rises but five feet above the water and is tiny: a 0.6 km*2* settlement flanked by two flippers of rock and heath.
Sein became an island some 9,000 years ago. It is a string of islets connected by dykes and pebbles, well known for the dangers of its waters, the Chausée de Sein, a vast zone of reefs stretching far out at sea, requiring numerous lighthouses, beacons, and buoys.
The average yearly rainfall on Sein is 787 mm. Estimated groundwater recharge is 300-350 mm per year. Due to the low level of the island's surface, the pumping of water from boreholes lowers the groundwater level with an extremely high risk of saltwater intrusion, and groundwater outlets on the island can only be accepted to a very small extent.
Vegetation is scarce. There are no trees or bushes but only fields, now mostly left to fall into fallow and delineated by ancient dry-stone walls acting as windbreakers. On the pebble beaches, shorebirds make their nests. There are herds, sheep and rabbits. On the other hand, the sea is rich with conger, lobsters, berniques, mackerels and dolphins.
The island's smallness and lack of relief exposes it to floods and marine erosion. Some experts say the islands get smaller with each heavy storm. Natural erosion is amplified by tourism erosion. The proliferation of rabbits is another major issue, as the burrows they dig allow the sea to rush under the ground.
Sein has 216 all-year residents. In summer (about 10 weeks), the population rises to 1,360 plus some 500 day trippers. The minute parcels of land have not been cultivated since the 1960s (which is also when the last cow left the island).
Sein is a municipality which manages its water resources locally and produces its freshwater in a local seawater desalination plant and then distributes it through a pipe network 8 km long with 328 subscribers. All households are covered by the network. Water on Sein is very expensive: 6.78 euro per $m^3$.
The yearly production of freshwater is 31,000 $m^3$. The plant uses 6-10 kWh to produce one litre. But this demand is not analogous to the need: the true need of Sein is 17,000 $m^3$/year. The roads on the island are made with concrete slabs with the water mains buried underneath. Big construction works have been going on for 3-4 years on the jetties of Sein, and the heavy machinery has crushed the pipes and is causing major leaks.

*See Photo 7 of Sein's surface on page no. 46*

## *EXERCISE B – The water of your islanders*

After the first lecture, you tried to estimate the freshwater assets of your island. Based on what you have learned in this second lecture, the next question is how much you are using, as a society. It can be answered in two ways, depending on the viewpoint: either (1) the consumer´s perspective, or (2) the producer's perspective.

### *1 – CONSUMER'S PERSPECTIVE*

#### *a) Human pressure*

As mentioned in the Tilos example above, it is necessary to define the island's "technical population". This will let us understand the human pressure on the island's water system.
First, for the residents, use census numbers. The residents don't come and go with the seasons, their number is the same all year round. Multiply them by 365 to get the number of total person-days.
Second, for seasonal residents, there are no census figures. The municipality administration should be able to make a good guess. The post office often knows how many post boxes there are = households, and a household is typically 2.3 persons. Water or Energy Management should know how many seasonal clients (taps, meters) there are. It will let you make an educated guess.
Third, for tourists, there are statistics at the municipality office and the Chamber of Commerce should have these figures (maybe they do not have the same numbers as the municipality). Another source of data is the ferry/ferries: check the number of passengers in winter, it will let you figure out how many trips the residents do in a three-month period. In spring and autumn, the increase in traffic would mainly be the part-time residents. Last but not least, the summer traffic increase would be the tourists.

Check back on Tilos to see how the total sum of person-days was calculated and do it yourself:

| | Spring | Summer | Autumn | Winter | Person-days |
|---|---|---|---|---|---|
| Residents | ........ | ........ | ........ | ........ | ........ |
| Seasonal residents | ........ | ........ | ........ | ........ | ........ |
| Visitors | ........ | ........ | ........ | ........ | ........ |
| **Sum** | ........ | ........ | ........ | ........ | ........ |

### *b) Water demand*

You can get your national average water consumption statistics from Eurostat. For resident islanders, reduce the number to 75%. For seasonal residents, let it be 100%. For visitors, assume 100 l/p, d. With the figures from the previous table, you can now calculate the total, theoretical water need of your island:

| | Person-days | l/p,d | **Sum** |
|---|---|---|---|
| Residents | | | |
| Seasonal residents | | | |
| Visitors | | | |
| **Sum** | | | |

Hotels, restaurants and bars use a lot of water, of course, but they are accounted for in the above tables. But there may be **other industries** on the island: fishing and fish processing, small-scale carpentry, shipyard, garage, service…? You can get data from the Water Agency, indirectly, or from the businesses, directly.

| | l/p,d | **Sum** |
|---|---|---|
| | | |
| | | |
| | | |
| **Sum** | | |

| | l/p,d | **Sum** |
|---|---|---|
| | | |
| | | |
| | | |
| **Sum** | | |

Agriculture is a large consumer of water. Farm water may include water used in crop irrigation or livestock watering.

If possible, make an estimate of how water demand changes with the seasons, such as in this diagram for Ithaka.

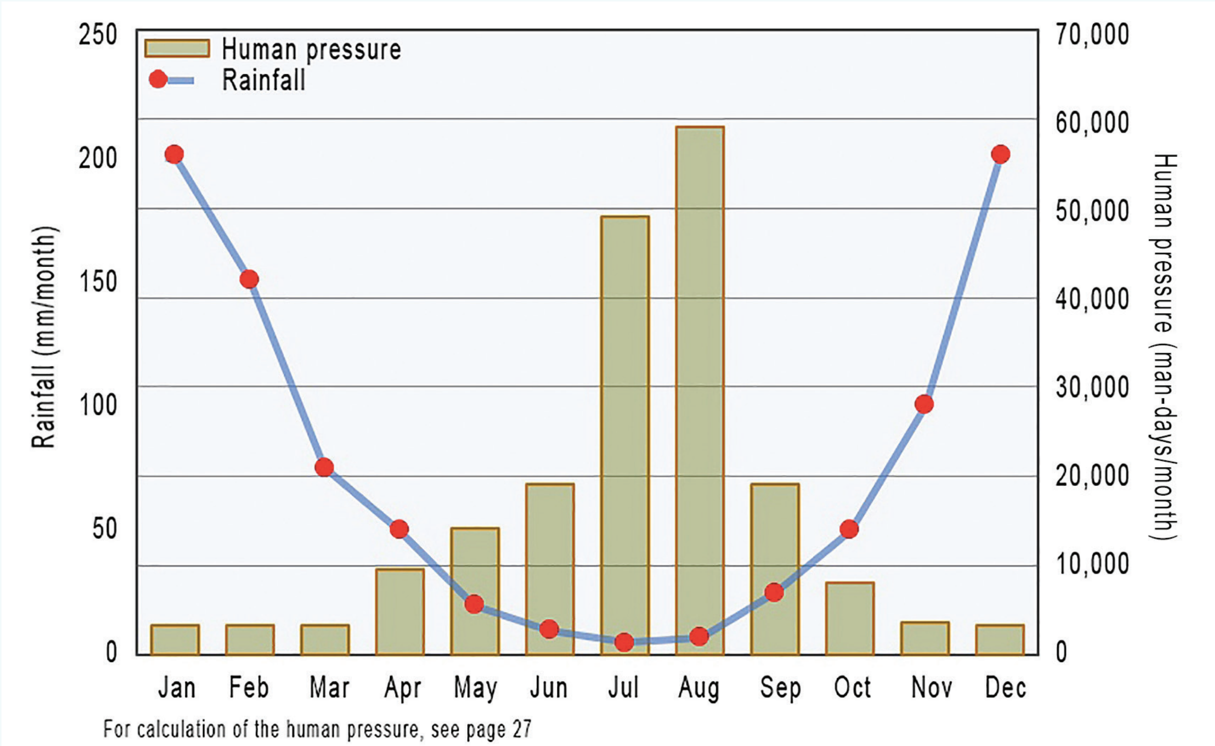



***Diagram 2**: Human pressure on Tilos peaks in summer when rainfall is at its lowest yearly point.*

## *2 – PRODUCER'S PERSPECTIVE*

The question can be viewed from the producers' perspective, simply by checking data from the water production unit(s). Again, there can be two points of view: what is pumped/processed, and what is billed. The difference between water being *produced* for the customers and water being *billed* to the customers will tell you about leakages in the system, which is one of the subjects of our next lecture. Water produced and water billed does not include water from private drills and rainwater collection. Both can be quite extensive. In the case of Ithaka, described in the next lecture, it is estimated at one third of the water use.
At the end of the day, you must use your common sense to interpolate the different perspectives to reach a fairly correct figure.

# The water of the community

People – islanders – can arrange part of their water procurement themselves, having a private well, harvesting rainwater, water slimming. That is very good but not the subject of this lecture, which is how to understand, design and develop the common freshwater system of the community.

The water system includes the catchment; raw water mains; the water treatment plant; pumping stations; transmission mains; the storage of water in reservoirs, cisterns and tanks; bulk, district, zone and domestic meters; distribution to domestic, agricultural and industrial users, and in the end, how to finance and administrate it all.

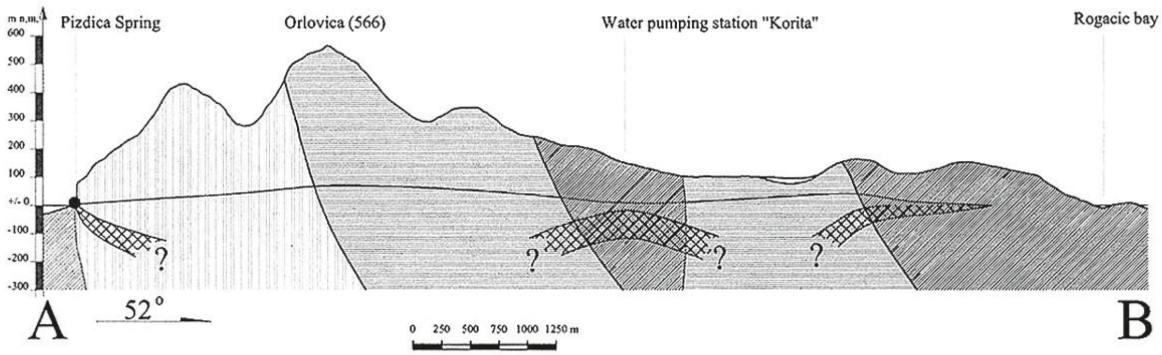
We will look at common water treatment, water distribution, wastewater and water management. We will give you some examples, before inviting you to do it yourself.


***Photo 2**: Houat hand pump. Last line on the sign reads: On Houat water is gold worth.*

## Potable water resources

As a consumer, you do not constantly think about where water comes from. You get water piped to your home and delivered to a tap or spigot and assume the water can be consumed safely as it has passed adequate treatment and meets drinking water regulations. On an island, life is slightly different: we have lots of saline water (we are surrounded by it on all sides). But we don't find enough freshwater easily.

### Excursion 7




***Cross section 2:*** *Cross-section of Vis. Observe the solid black line representing the groundwater level in the rock. Typical of limestone rock, groundwater flows quite quickly out to sea. The fresh - salt groundwater boundary is just below sea level, meaning the fresh groundwater magazine is not big. To prevent salty groundwater on Vis, great caution is needed when pumping groundwater.*

**Vis**, a Croatian island in the Adriatic Sea, 55 kilometres from the mainland, covering a surface area of 90 $km^2$. It has three hill chains and two valleys. The highest point of the island is Hum at 587 m above sea level. Rock is composed of cretaceous limestone and dolomite; Triassic and clastic rocks.
Vis has a Mediterranean climate with long and hot summers. Years without rain for 3-4 months are not rare. Winters are mild (average January air temperature is 100C), the average yearly rainfall is 800 mm. There are no surface water flows except after heavy rainfall (typical for Adriatic islands).
The groundwater formation is estimated at approximately 400 mm and takes place almost completely during the winter. The groundwater flows quickly into the limestone that dominates

the island's bedrock and the groundwater surface is very close to the sea level, which is not usually normal in, for example, granite bedrock. This indicates a major problem in obtaining freshwater from the island's groundwater.

3,460 persons live in the island's two municipalities. Ten times the population comes to visit every year = 36,750 tourists, spending some 200,000 days on the island. The pressure on the island's freshwater system is not so high, the total demand is about 139,000 $m^3$ per year.

The leaks in the 85 km-long distribution system account for about 25% of the water use.

The water supply system of the island uses two sources of drinking water: drilled wells in Korita and the fresh water spring of Pizdica. The Korita pumping station is located in the interior of the island above five drilled wells containing water at a depth of approximately 160 meters. Water is pressured into a pumping pool from where it is distributed to consumers (20 l/s). The Pizdica spring is located in a gallery drilled in solid rock close to the shore in the bay of Komiža, deep into the Hum mountain.

To visit Pizdica, you leave the road at a height of about 250 meters and descend on a pathway which becomes a serpentine trail down the mountainside. The route becomes more rugged, and you can easily slip on the simple stairs and plateaus. There are wild roses, blackberries, hedge flowers, rosemary and St. John's wort. Through many turns, bends and staggering dumps, you eventually land on a beach with decayed buildings.

Vis was a floating fortress with bunkers and caves for torpedo boats during Yugoslav time. No visits were allowed. The Pizdica source was the only known natural water resource of the island and therefore carefully guarded by the military, who had a posting there and carefully guarded it from attacks of all kinds. Two iron doors, 50 meters apart, close the double entrance to the spring, connected by a crescent-shaped gallery, designed to bear the pressure of a 500-kiloton bomb. A heavy steel door leads into today's pumping room, where a small side door leads through a long narrow tunnel deep into the mountain, with the water pipe from the source on the floor. It is dark with simple lamps every ten meters. The passage turns once more. The pipe has taps into the mountain. You hear the water gurgle, and, after another bend, you are at the source.

It is a small basin, 2 x 2 meters, one meter deep, giving 4 litres per second during summer, 3-4 times more during wintertime. The water is cold and clear and tastes a little salty.

It is spectacular. First the steep descent, then the oversized steel and concrete defence of the source, followed by today's impressive engineering solution to extract the water of the source, and finally, at the bottom of the mountain, the ancient, mysterious source, the origin of all life, the holy water. The Croatian word Pizdica literally means "small vagina" and the spring is referred to as "the pussy fountain".

From an engineering point of view, drinking water is a precious provision which has to be found, extracted, purified and distributed among us humans. From a more poetic perspective, a freshwater spring is not only a subterranean spring but also a subconscious, important source of legends, dreams, nightmares, poetry, music and myths.

***Photo 3**: View of the bay with mountain entrance*

***Photo 4**: Tunnel leading to the spring deep into the mountain*

***Photo 5**: The pumping room*

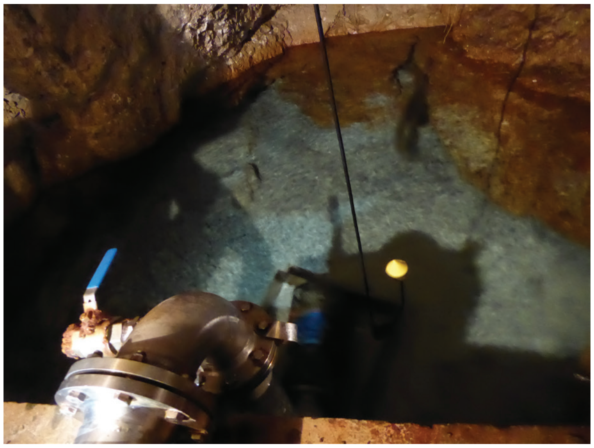


***Photo 6**: The secluded spring in the middle of the mountain*

Except for groundwater, **seawater** can be used if run through a desalination process described below and we can use **rainwater** harvested on roofs or yards and flowed through a gutter leading to filters that, depending on their properties, may retain particles from the size of leaves, pebbles etc. down to the size of dust. Then the filtered water goes into a storage tank (reservoir) that is usually built into the ground or placed in the basement with a storage temperature ideally below 18 °C. Rainwater is suitable for non-drinking use, i.e. toilet flushing, cleaning, watering and, if thoroughly filtered, also in industry. It can be used for drinking, provided it is properly disinfected by UV lamps, chlorination, ozonation etc.

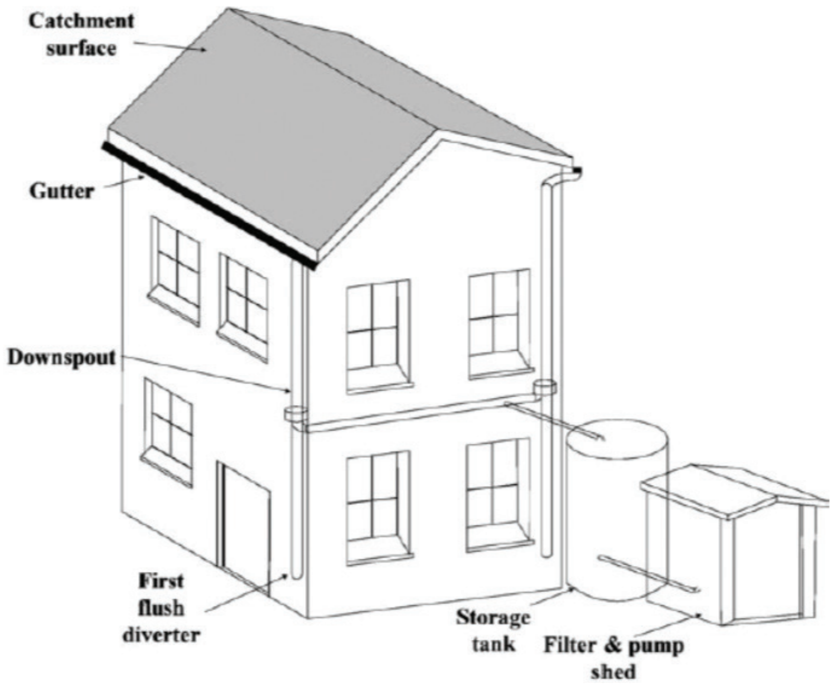



***Illustration 3**: A typical roof rainwater harvesting system in Ireland*

## Excursion 8

**Ithaka** is an island of 96 km$^2$ in the Ionian Sea. It largely consists of a series of folded Jurassic to Eocene limestones. Its western side is arid and steep, and its eastern side is green and accessible. It rains mainly on the eastern part of the island, as the west side is in the "rain shadow" of Kefalonia. The winter precipitation is high, about 600-700 mm and allows for abundant groundwater formation in the eastern part of the island. However, the limestone mountain offers limited groundwater magazines. Most of the water flows relatively quickly to the sea unless sealing bedrock layers are varied with limestone. The withdrawal opportunities may be average

in some places for these reasons.
The groundwater surface is rather low even though large parts of the island's land surface are much above sea level. This causes problems with groundwater outlets in wells, as the outlets further lower the groundwater and thus increase the risk of water becoming salty.
The resident population is 3,100. Technically speaking, recalculating the impact of summer residents and visitors, the human pressure on the island is equivalent to 6,182 all-year inhabitants. On a winter day, the people of Ithaka need 250 $m^3$ of water, and on a hot summer day when water consumption peaks, 1,000 $m^3$. By tradition, islanders collect rainwater during winter and store it in tanks under their houses for summer use. Some 90% of the active dwellings on the island have cisterns of 20-150 $m^3$. It seems that the municipality of Ithaca produces 67% (165,000 $m^3$) of the total yearly amount of water needed on Ithaka, (247,000 $m^3$), indicating that the islanders' use of rainwater equals one third of the demand.
The municipality has built four wide rainwater collectors, but frequent small-scale earthquakes are destroying them.


***Photo 7:*** *Ithaka landscape with four rainwater tanks*

Another source of water is our own **wastewater**. Water is not consumed, it is just used. There is more wastewater than ever and over 80% of the world's wastewater is released without treatment. After treatment, wastewater can be reused for irrigation, aquifer recharge, industrial processes, heating/cooling, and as potable water.

## *Potable water treatment*

Some freshwater requires treatment before use, sometimes even water from deep boreholes, wells and springs. Some of the disinfection treatments it is subjected to include techniques such as filtration, chemical treatment and exposure to ultraviolet radiation (including solar UV) to reduce levels of waterborne diseases.

We can treat water by boiling which kills waterborne pathogens but this requires abundant sources of fuel, and can be very difficult for consumers, especially where storing boiled water in sterile conditions is hard to achieve.

**Desalination** is a type of water treatment, very appropriate on islands with access to immense volumes of saltwater. It involves the following steps: the seawater is transferred to the desalination plant through large pipelines (intake). The water is filtered to remove debris and floating particles as a pre-treatment. Salt is removed with the use of semi-permeable membranes and high pressure in a process called reverse osmosis, a method widely applied to separate salt from water. The process is very energy-consuming.

Desalinated water is further treated mainly to avoid corrosion in pipes and taps, to avoid bacterial infection, or to improve its taste by passing it through carbonate rocks (post treatment). The water finally enters the distribution network. The output volume of desalinated water is approximately one third of the incoming volume. The remaining water is used in the operation of the plant and includes the high salinity brine which is discharged back to the sea.

Desalinated water can supplement municipal water supplies and it is also used in industry and irrigation. The limitations for using desalinated water for irrigation are mostly economic, as it is very expensive to produce. Furthermore, with the minerals removed, its suitability for irrigation has been questioned.

Water treatment can also include running imported water through UV filters, as is the case with the water shipped to Inis Oírr, or treatment of the water that has been pumped through the 160-kilometre long pipeline to Vis.

## *Water distribution*

After treatment, water is stored in reservoirs and fed to the consumers by gravity or by pumping through pipes. Pipes are generally laid below the road pavements, and, as such, their layouts follow the layouts of the roads.

Leakage of untreated and treated water from pipes brings high costs to the system and reduces access to water. Leakage rates of 50% are not rare in water distribution systems.

Distribution can also be non-piped: water trucks, bottled water and simply fetching water with a bucket from a village pump.

### Excursion 9

Let's revisit **Houat**, a commune in the Finistere department of Brittany. There are 242 people registered as permanent residents on Houat, there are 600 summer residents and some 500 people visit the island for one day during the three-month summer season. The human pressure on the island is 202,330 person-days but, as always on islands, very uneven, peaking in summer when water is scarce. A hot day in July, almost 1,000 visitors, plus 600 summer residents, plus 242 all-year residents can be on the island = 1,842 p/2.9 km$^2$ = 635 p/km$^2$.
Data from the municipality reveal that a resident household on Houat uses 70 m$^3$ of water per year on average. The total water demand can be estimated at 13,238 m$^3$.
Running municipal water was installed on Houat in the 1970s, using rainwater, a well and a spring. These were supported by a reverse osmosis desalination plant with a capacity of 50 m$^3$/day, providing 20 percent of the needs of the island, being estimated at 100-120 m$^3$/d.
In the 1980s, a search was undertaken for additional water sources. Four 50-meter-deep drills were made. Three of these were put to work, the fourth one contained excessively salty water. In 1990, a new 100 m deep drill was made next to the stadium which is today the island's main source of water.
The water from these drillings is pumped to a raw-water reservoir holding 2,600 m$^3$ of water, processed through a filter system and then stored in 4 reservoirs of 2,500 m$^3$ each, close to the raw-water reservoir. In two water towers of 200 m$^3$ each, located above the castle ruins, potable water is stored before distribution. The water is distributed through a pipe network covering all households. The cost of this infrastructure leads to a water price on Houat of 2.06 euro/m$^3$.

## ***Water management***

Water management is about developing, leading and controlling the use of water resources. It includes personal, local, industrial, community, municipal, county, regional, national and international responsibilities as laid out by law, regulations, directives, practices and budgets.
It is a sub-set of water cycle management. Ideally, water management planning takes into consideration all the competing demands for water and seeks to allocate water on an equitable basis to satisfy all uses and demands. In practice, this is not an easy task. If water shortages are present, water management includes making difficult decisions about how to allocate water resources. Utilities may limit availability of water to certain times of the day to cut down on usage and citizens may be encouraged to conserve water as much as possible. Fines and tiered

pricing structures can be used to penalize households with high water usage to promote conservation.
In addition to considering the needs of individual consumers, people in charge of water distribution must think about industrial and agricultural resources of water. Interruptions of water supplies can result in costly delays that may have a ripple effect.
In the end, it all has to be financed and administrated, too.

## Excursion 10

**Lastovo** is an island of 47 km$^2$, located 50 kilometers out in the Adriatic Sea, where almost everything is 46: the area is 46 km$^2$, there are 46 churches, 46 fields, 46 beaches/bays and 46 islands/islets. The 792 islanders live in six villages. With visitors and summer residents, the human pressure is equivalent to 1,509 residents. Lastovo is the most remote of the Croatian islands and remoteness creates some disadvantages, such as time-consuming transports and high prices, but also some advantages: a well-developed public service, very clear blue waters and very clear skies. The island is situated in a clear blue sea with 50 metres visibility and boasts to be one of the least light-polluted places in the world.

Lastovo obtains its freshwater from three sources:

1. A mainland pipeline from 1982, a submarine pipeline built by a Norwegian company from Korčula to Lastovo over the 80-metre deep, flat, sea bottom from Korčula, 17 km away. The water originates from the mainland and comes via pipeline from Neretva to Pelješac over Korčula to Lastovo, where it is fed into the reservoir at Sveti Luka. The water is thus transported 160 km in total.

2. The inhabitants of Lastovo collect and use rainwater to a large extent.

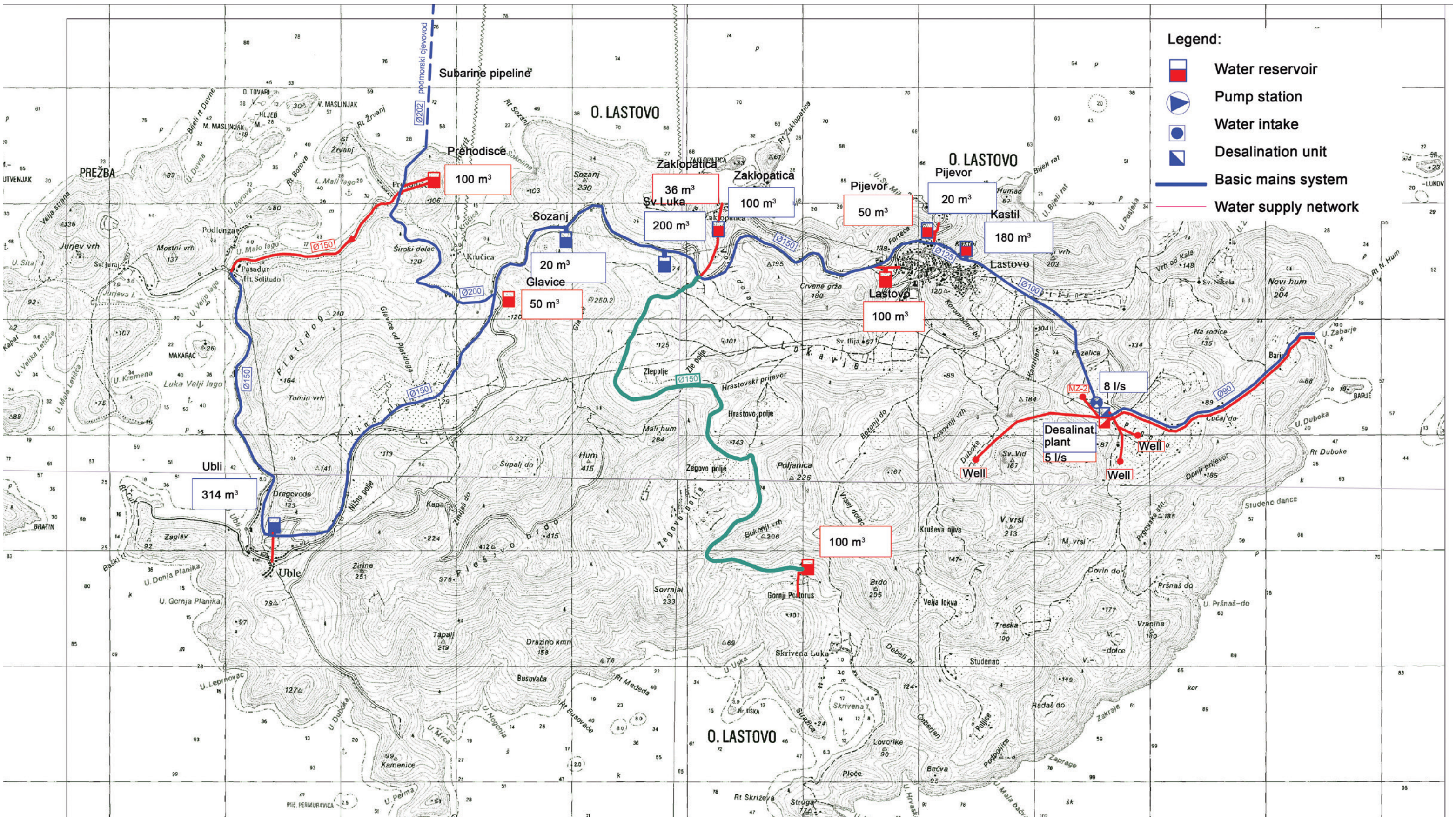
3. The main water supply system of the island of Lastovo is based on the use of three drilings in Prgovo. 5 l/sec of water is processed through the desalinization plant in Prgovo field. The desalinated water is pressurized to the central water reservoir, from which the water is further gravitationally transported to other reservoirs on the island. The desalination system works mainly at night and fills the main island water reservoir so at daytime it is under a pressure of 3 to 5 bar.

Lastovo needs 51,000 $m^3$ liters of freshwater to meet the human pressure on the island, but produces 73,304 $m^3$ of which 30,645 $m^3$ is lost in leakages. The consumption of municipal freshwater is 42,659 $m^3$ and the rest is obtained through rainwater collection, about 25 percent of the demand ~ 15,000 $m^3$, plus water for the animals.
Lastovo is a municipality and has a technical director who is responsible not only for the procurement of water but also for calculating its consumer price, which is 2.77 euro (1.5 euro + VAT) per $m^3$ for residents:

| | Cost in kuna | Cost in euro |
|---|---|---|
| Base price | 9,8 | 1,34 |
| Charge for protecting the water | 1,35 | 0,19 |
| Charge for using the water | 2,85 | 0,39 |
| Charge for the concession | 0,29 | 0,04 |
| VAT | 1,27 | 0,17 |
| **Sum** | **15,56** | **2,13** |

There is also a sewage charge of 30%, meaning the price for the consumer will be 20.23 kuna = 2.77 euro.

***Map 4**: Map of water supply network on Lastovo (right)*




The 1992 UN Dublin Statement on Water and Sustainable Development stated that:

**1** Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment.

**2** Water development and management should be based on a participatory approach, involving users, planners and policy-makers at all levels.

**3** Women play a central part in the provision, management and safeguarding of water. Institutional arrangements should reflect the role of women in water provision and protection.

**4** Water has an economic value in all its competing uses and should be recognized as an economic good.

It was followed by the European Commission Water Framework Directive in 2000.
This book, in a simple form, addresses the issues of water management with a special focus on islands.

## ***EXERCISE C – The water of your community***

This is the last exercise aimed at mapping out the water system of your island. It consists of five simple questions – although the answers are not so simple. It is best done sitting down with the water manager of the island. You will want to know: (1) What are the water sources, (2) How is the (raw) water treated, (3) How is water distributed, (4) Is wastewater treated, is it just a problem or is it a resource, and (5) How is the water system managed?
Having answers to these questions and the ones from exercises 1 and 2, you will have created a kind of dashboard showing the overall water condition of your society and whether the system is at risk of running dry.

### ***1 – WATER SOURCES***

Which are the main sources of water for the water scheme on your island?

| Source | Yearly intake ($m^3$) | Comments (quality etc.) |
|---|---|---|
| ........ | ........ | ........ |
| ........ | ........ | ........ |
| ........ | ........ | ........ |
| ........ | ........ | ........ |

### ***2 – WATER TREATMENT***

Most probably, you have a desalination plant on the island.

The plant is in ☐ good ☐ average ☐ bad condition

What is the geographical location of the plant and why was it installed there?

How is the desalinated water used (percentage):

Household: ........
Tourism: ........
Industry: ........
Agriculture: ........

How much electricity does the plant use to operate and how is it produced?
What is the yearly cost of the desalination process, total and per $m^3$?

## 3 – WATER DISTRIBUTION

You might either get a map of the distribution system including storage (reservoirs), pumps, pipes and meters, or you will have to make one yourself.

The pipes are in ☐ good ☐ average ☐ bad condition

How extensive are the leakages?

## 4 – WASTEWATER

Is there a common sewage network?
How is wastewater treated?
Is wastewater reused for any purpose?

## 5 – WATER MANAGEMENT

Is water management local or in cooperation with other islands/the mainland?
How is it organized?
Which regulations are there on community, municipal and regional level regarding water use, water investments, wastewater, rainwater use, agricultural and tourism use?
What is the cost of water (household/business) and how is the price calculated?
Are there/have there been any water saving activities?
What future plans are there regarding water issues?

***Photo 8:** Sein is a flat island without heights and a very limited fresh groundwater supplies. Water desalinization is energy-consuming and demands additional water purification, making drinking water on Sein very expensive. The water intake is just below the lighthouse on the picture.*

***Photo 9:** "You'll find him [Eumaios ] keeping his swines where they feed by Corax Rock, near the spring of Arethusa, drinking its dark water", says goddess Athena to Odysseus when he returns to Ithaka after twenty years. This view is probably from where Odysseus lived.*

Lecture 4

# The water we can save

After having talked about the water we have (lecture 1), the water we use (lecture 2), and the water we produce and distribute (lecture 3), it is now time to talk about saving water. If you browse about "saving water", you would get the impression it is a private task, urging you not to let the water run when brushing your teeth, taking shorter showers and eat less meat. We see serious water saving as a collective task requiring citizens, civil servants, politicians and businesses to perform a concerted set of actions including (a) communication, (b) smart technology and (c) wise governance.

Generally speaking, we produce more water than we use, and we don't need as much water as we use. It's like the angel's share in whisky making, when a large part of the liquid evaporates in the process (about 24% for a 12-year old scotch).

What if you challenge yourself to save a certain amount of the water used on the island? How could it be done? What can we learn from others? Are there any water-waste fighters around?

It seems actions with proven results can be divided into three groups:

(a) **Clever communication** to make water users understand how much water they use, how this is affecting their society and their environment, and how to save water.

(b) **Smart engineering** with respect to technologies to reduce water consumption in households, in official buildings, in agriculture and in industry, to reduce leakage in networks and pipes, for more efficient desalination / reverse osmosis.

(c) **Wise governance** which includes pricing of municipal water, rainwater use, the reuse of wastewater, and regulations for hotels, industries and households.

Let's go look for the angel's share in water.

# Clever communication

Human communication is a tricky thing. It can be *information* by which we mean one-way communication when someone – your superior, a teacher, the Tax Authority – is trying to make someone else understand something. One person talks and the other one listens. The one talking is not really interested in getting any feed-back, just in getting the other one to understand.

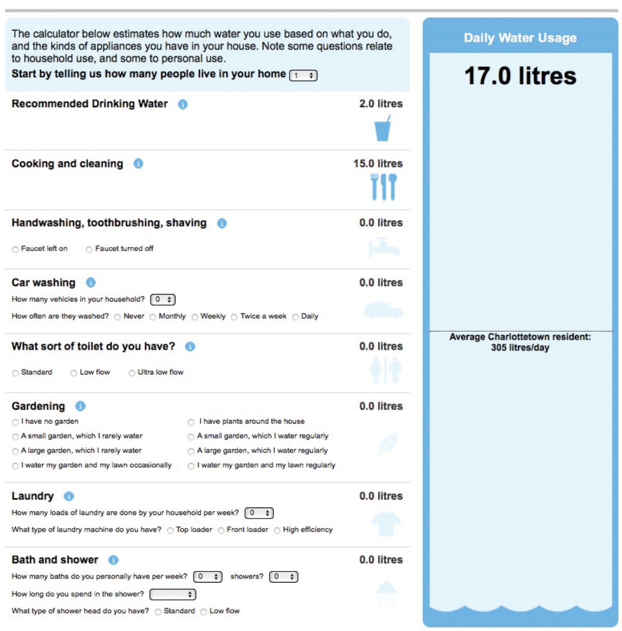
Communication can also be a *dialogue*, a two-way interaction between people who are genuinely interested in what the other has to say. Both are listening, both are talking. It can be a couple talking at the dinner table, a round-table discussion with some interesting people, or a TV debate (even though debates tend not to be dialogues, but parallel monologues). Sometimes the dialogue involves many people. Technological progress in the last twenty years has allowed the so called digital democracy with millions of people communicating via social networks today. General elections are also an example, of a very large dialogue. We like to call this a *demologue* (demos is Greek for people, logos is speech).

## *Information*

Information can be focused on facts, it can be fun, friendly, angry or even furious. It depends on who you are and what you want to say.

### Example 1

On Prince Edward Island is a Canadian island covering 5,600 km$^2$ with a population of 142,000, famous for being the home of *Anne of Green Gables*. In the summer of 2012, the dry weather shone a spotlight on water usage in Charlottetown. The city gets nearly all its water from the Winter River watershed. The drought caused the Brackley Branch of the river to run dry six weeks earlier than it did in 2011. The city was nearing the water use limit from the watershed allowed in its provincial permit, but the Winter River Watershed Asso-



ciation believes the amount allowed in the permit is unsustainable. They wanted the province to reduce the amount of water the city is allowed to take. The situation prompted the city to ask residents to conserve water. To help citizens see how much water they were using, the Canadian Broadcasting Corporation (CBC), a Canadian public service company, launched a **water usage calculator** on their website.

***Photo 10**: The water usage calculator (left)*

### Example 2

Komiža harbour is located near the Pizdica spring on the Croatian island of Vis which we studied in lecture 3.  The pressure from humans is very uneven, peaking in summer. When water is most scarce, the population rises approximately 2.8 times. On a hot day in August, the island hosts 6,000 visitors plus 3,500 residents = 9,500 p/90 km$^2$ = 108 p/km$^2$.
Signs in the harbour explain that there are water shortages. Guests and boat owners are made aware and asked to understand that **water is for drinking, not for showering and boat cleaning**.

### Example 3

You could send a **postcard** from a Greek island, issued by the Non-Conventional Water Resources (NCWR) programme. The postcard says: "Greek islands face a serious water issue and YOU can help! The water on the islands is often not sufficient, while the increasing demand combined with climate change require our active participation. Using as much water as you need is critical because every drop counts. Say no to water waste and contribute to the water saving effort across the islands."


***Photo 11**: Greek postcard (back) used as a water saving information tool.*

## ***Dialogue***

When someone talks to you and wants you to answer, communication reaches another level. Sending a postcard is great, but what if someone actually listens, and reacts?

### Example 4

Hotel rooms in the Leopold hotel in Brussels have a sign with the following text in three languages: "Leopold Hotel Brussels has adopted a sustainability policy. You can help us to reduce both water consumption and the use of cleaning products by reusing your bath towels. A free drink per stay at the bar of the Brasserie will be offered to every guest accepting to reuse their towels."
They are making much more than just sending you a postcard. They are not addressing you in a general way, but actually making you a kind business offer: you give up that, we give you this. They realise sustainability is not a one-man game, but a joint effort and will reward you for doing your part. This is not the usual hotel monologue, it is a simple, creative and nice way of having a dialogue on water saving. Thinking out of the box, rewards need not necessarily be financial. As a visitor, you may appreciate to be involved in taking care of the island you visit, not just using it for your own purposes. People seek unique, new experiences and even 400-litres-a-day luxury hotel water consumers may consider water slimming – if we make it a singular, valuable treat.

### Example 5

Water was always scarce on the Greek island of Santorini. There is only one spring, perched on the rocks next to the church of Zoodochos Pigi (the life-giving spring), alongside the road that leads to ancient Thira. Islanders developed crops like vines and olives that could survive with only moisture from dew. They stored rainwater in elaborate underground reservoirs that survived to this day, although many have fallen into ruin or remain unused because tourism has brought sufficient revenue to the island to enable them to construct desalination plants.

In the early Summer of 2016, an interdisciplinary group of Cornell University students and staff visited Santorini. With the help of the Santorini Water Board, the Mayor of Santorini, The Atkinson Center For a Sustainable Future, the Cornell Institute for European Studies and the Global Water Partnership, they developed **Water Walks** through Santorini. Their purpose is to acquaint locals and tourists with water resources of the island. Walkers will gain an understanding of freshwater availability on the island, the water and its role in the history of Santorini, water management practices, and ideally, walk away with an interest in sustainable water management for the future of Santorini.

***Photo 12**: A chapel built at the entrance to the spring on Santorini*

### Example 6

In areas dependent on tourism, and particularly in the Aegean islands, water demand reaches its peak both for irrigation and for domestic supply in summertime. On some islands, the summer peak can reach up to thirty times the domestic needs of the permanent population. As the domestic supply takes priority over irrigation purposes, conflicts invariably arise between the municipal water suppliers and the local farmers.

**"The Gift of Rain"** is a schoolbook, an educational material intended for students of late middle and secondary level (10-14 years). It addresses the old, mostly abandoned water use practices traditionally applied in the Cyclades islands over the centuries, as well as the modern techniques than can be applied today in homes and hotels in order to collect, economise or recycle water.

## *Demologue*

As defined above, a demologue is when many people talk to each other.

### Example 7

**Fix-a-Leak-Week** campaigns are run by the US Environmental Protection Agency (EPA) from coast to coast every year. Leak detectives are engaged and given leak detection

checklists, grabbing their sleuthing gear (dye tabs, wrench and leak checklist) to find and fix common households leaks in bathrooms, toilets, showerheads and faucets, outdoors in spigots and many other locations. 5.7 trillion litres have been saved in ten years.
The EPA also runs the "**WaterSense at Work**: Best management Practices for Commercial and Institutional Facilities", has a "WaterSense Label for Homes", and in May 2014, it started the **H2OTEL Challenge.** Hotels get technical resources, including a Water Use and Savings Evaluation Tool - a spreadsheet designed to help hotel operators and facility managers assess their water use and identify and prioritize best practices to implement; Training webinars on hotel water-saving topics; Recognition tools, logo and a certificate; Case studies and lessons learned from other hotels that successfully saved water.


***Photo 13:***
*Fix-a-Leak Week ad*

### Example 8

Oxfam - the Oxford Committee for Famine Relief , which is a confederation of humanitarians fighting poverty and injustices in more than 100 countries – have designed a clever and complete **Water Week for Schools** intended for young people to learn and think critically about water issues, before taking informed and meaningful action.
The Water Week material includes a Teacher's Guide, slideshows, session plans, learner action, campaigning and fundraising guides. There is background country information about Niger, Uganda, Pakistan, Tajikistan, Chad, Sudan, Liberia, Angola, Zimbabwe, Ethiopia and Haiti.
Water Week can be held at any time of year, but many schools find the summer term works well.
Slaven Kevo, the Water Manager of Vis, strongly believes island schools should pay more attention to water. He is dreaming of a "water week" focused on water issues in the world, in Europe, in Croatia and on Croatian islands, engaging kids in water metering ("how much water does your family use per week for different purposes?"), how much water is used by tourists and industries, what is water, how can water be saved, how do others do it, maybe making a water conservation campaign?

## Example 9

Malta is an island of 316 $km^2$ in the Mediterranean. With its little sister Gozo of 67 $km^2$ it has just under 450,000 residents, making it one of the smallest, most densely populated and most water-stressed countries of the world. The tiny islands don't have rivers or lakes, so tap water is sourced from a combination of desalinated seawater and groundwater.

Potable water is distributed throughout the islands through a dedicated distribution network which provides potable water to every household. Over the years, the national water utility has carried out an extensive leakage detection programme to minimise water losses and improve its efficiency.

The water scarce conditions of the Maltese islands have instilled a sense of water consciousness within the Maltese population. In fact, on average, a person in Malta uses 120 litres of water per day, making Malta one of EU's countries with the lowest water consumption rates per capita. The existing tariff structure also encourages efficient use of water at the household level with the adoption of a rising block tariff system ranging from 1.39 euro to 5.13 euro per cubic meter.

To further increase the awareness and understanding of the importance of water in Malta, a Water Conservation Awareness Centre was inaugurated in 2017. The centre hosts a number of educational and interactive installations to support national educational initiatives on water management and conservation. The centre is called Ghajn (pronounced AIN) which is an old Maltese word for spring. This project was managed by the Energy and Water Agency, the entity responsible for policy development and implementation. The centre offers smart games for kids where they can interactively understand the water cycle, or be the water manager of a city.

The centre is equipped with solar panels on the roof to generate renewable energy and cisterns which harvest rainwater runoff. The available water is then used for secondary purposes such as toilet flushing and landscaping of the centre grounds.

To further complement these initiatives, Malta will shortly launch a National Water Conservation Campaign targeting the main water-using sectors in the Maltese islands. This campaign will include both traditional and innovative ways of reaching out to consumers. Innovative approaches to convey the water conservation message include:

- The use of demonstration sites: a representative sample of households will be refitted under the condition they let themselves be measured before, during and after, and willing to accept visits. This will also be done with a representative sample of agriculture/farms, and later with industries and hotels;
- Targeted assistance at the household level including a moving exhibition with an ideal

water household "live" including the option to book a water household consultant;
- The use of information technology to inform consumers of their consumption patterns.

What a superb package of water saving information!

***Photo 14**: A group of children in front of the Water Conservation Awareness Centre on Malta*

## Smart engineering

Technical solutions can be small-scale and/or big-scale.

### *Use of rainwater*

Rainwater collection and storage solutions are still in use on islands, and it is possible to purify rainwater so that it can be used for drinking and cooking. We all have the right to drink the water we please, but we don't have the right to sell it to others unless it is controlled and approved by the authorities. Rainwater harvesting isn't rocket science, but it is still a technology.

#### Example 10

On Cape Clear Island, one of the two Irish Summer Colleges run by the co-op, collects rainwater from the roof, stores it in a harvesting tank, pumps it to a storage tank on the attic and uses the rainwater to flush the toilets in the college. If there is not enough rainwater, ball cocks in the storage tank will automatically switch to the municipal water system.
The other college does the same thing but uses water from a stream practically running through the school building.

#### Example 11

Pretty much every house on Inis Oírr had a rainwater tank, but when the pipe system was installed in 1971, reservoirs were converted into storages etcetera. Fifty years later, the island co-operative is running courses in rainwater harvesting, water sampling, septic tank repair and maintenance, as part of their work in facilitating and encouraging good and innovative environmental practices.

*See Illustration 3 on page no. 37 for a Typical rainwater scheme for an Irish house*

### *Household water saving*

Older water closets use larger flush volumes compared to modern ones: during the latter part of the 20th century there were toilets with about 6-10 litres flush volume, while toilets installed in the late 1990s had flushing volumes as low as four litres in many countries.

During the last decade, new toilets give you a choice between two flush volumes: 2 and 4 litres.Washing machines and dishwashers from the 21st century are more water-efficient than older machines. Water taps in kitchens and sanitary facilities (especially showers) save water due to a change of quantity and size of the outlet holes. Sometimes, technology can be surprisingly simple.

## Example 12

The WiCi is an ingenious French product. The water you use to wash your hands is stored in the sink. Next time you flush the toilet, you use this water to rinse the toilet whereafter you wash your hands in clean water and fill up the sink, again. As we flush away some 10,000 litres a year per person, this recovery of water from the washbasin is smart water saving.
A simple WiCi model costs 399 euro. On Sein, where the consumer pays 6.78 euro per $m^3$ of water, the return on investment for a couple with two children would be two years.

***Photo 15***: *WiCi: the water you use to wash your hands will be used by next person to flush the toilet, and so on.*

At the community level, an authority can promote or even distribute simple, household technology for free.

### Example 13

The WiCi is an ingenious French product. The water you use to wash your hands is stored in the sink. Next time you fla On Inis Oirr, the 25 houses that use most water had new showerheads, taps, toilets and bags in cisterns installed two years ago. The products installed were all easy to retrofit and did not require breaking into the plumbing / water supply / pipe work. The result is a reduction of 2.3 million litres in water consumption in these 25 households during two years. With 589 litres a day as the average amount of water for a typical Irish household and a typical household of 2.6 people, the people living in these 25 houses have reduced their water consumption by 38%, from 128 litres/person/day to 79 litres/person/day.

On Sein, 300 ECO-sets have been distributed free of charge to the households by the Region of Brittany, ADEM and AIP. At the moment, there are no figures to show the saved amounts of water.

ush the toilet, you use this water to rinse the toilet whereafter you wash your hands in clean water and fill up the sink, again. As we flush away some 10,000 litres a year per person, this recovery of water from the washbasin is smart water saving.

A simple WiCi model costs 399 euro. On Sein, where the consumer pays 6.78 euro per m$^3$ of water, the return on investment for a couple with two children would be two years.


***Photo 16****: The "Pack eco-citoyen" distributed on the island of Sein*

## *Monitoring*

Keeping a keen eye on consumption.

### Example 14

A US company has developed a device called **The Fluid**. It measures the pressure and flow of water consumed in an apartment or a hotel room, and can monitor for what it is used: flushing the toilet, taking a shower or running the washing machine, all of which create different patterns. This can be displayed on a smartphone or monitored on a screen in the lobby of a hotel that really wants to "go green", involving the guests in common water saving without being repressive.

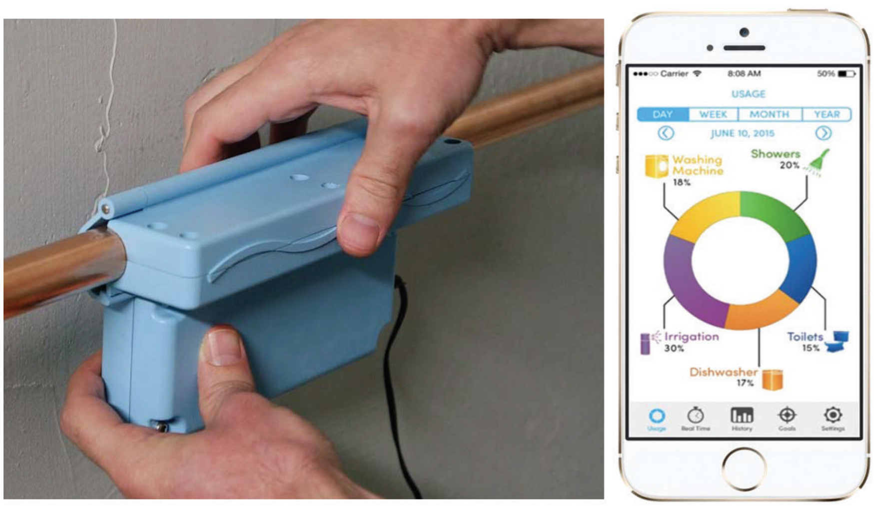



***Photo 17**: The "Fluid" measures the pressure and the flow of water used in apartments or hotel rooms.*

### Example 15

The impressive information technology with which the water system of Vis can be supervised, calibrated and developed. Good, accurate, reliable data is the basis for just and efficient saving and conservation efforts.

Groundwater discharge from a borehole can be stopped when at risk of desalination, and water discharge switched to another "magazine", letting new fresh groundwater flow into the borehole area. This might take some time but you can usually restart the borehole after the next rain period.

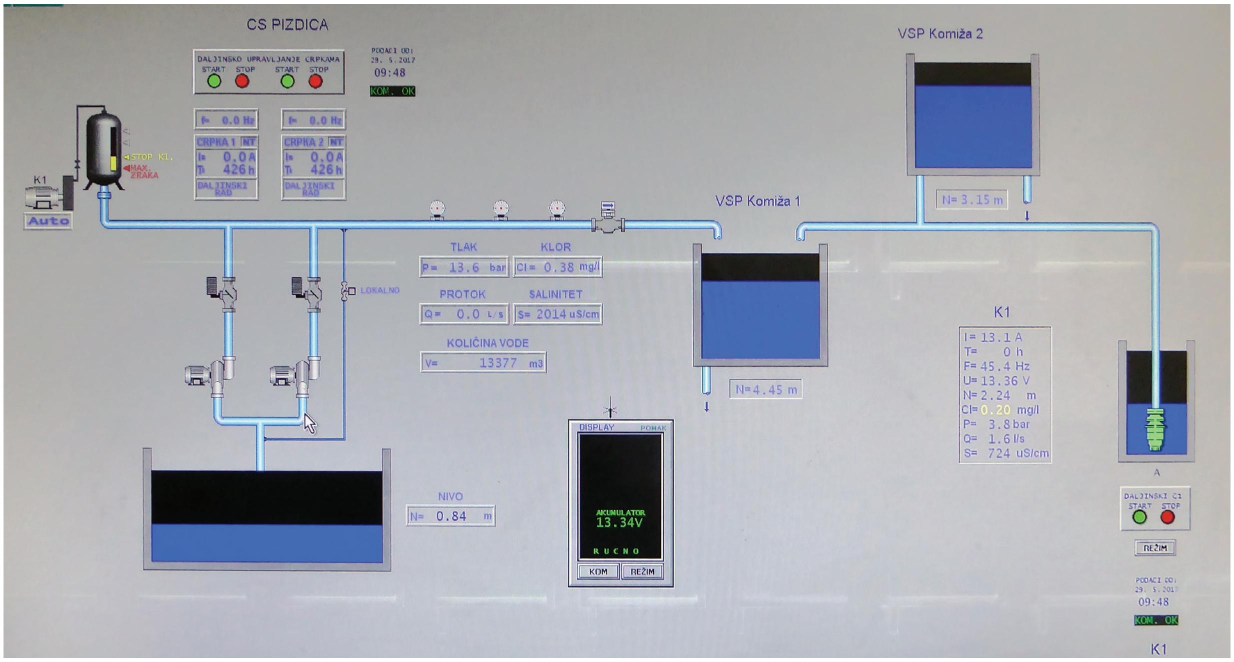



***Photo 18:*** *Control panel in Vis Water Management Centre allows engineers to optimize water pumping at all time. Displayed is status of the Pizdica spring (left screen side), pressure, flow and water composition (centre of the screen), and status of main island pumps and reservoirs for consumer distribution (right screen side).*

## Example 16

Favignana is an island to the west of Sicily. Its area is 20 km$^2$ and the population is 4,300 people. The A. Rallo School is one of Italy's small island schools, facing organisational and didactic challenges every day, ranging from the size of the structures to the multi-age classes, from the reduction of the staff allocated to frequent teachers' turnover jeopardising teaching continuity. It is therefore especially admirable to see how the school has engaged in a water consumption assessment study.
The school was built around 1980 as a one-floor building with 96 pupils and 16 teachers. It has double piping for both tap water and well water (the latter is used for flushing water, sweeping and garden irrigation). It has been shown that male and female students have different behavioural patterns, that toilet flushing was 54% of the total consumption, and that water leakage was 55% of the total water consumption. Obtained data were used to implement water saving at the school level. "Ignorance is the root and stem of all evil", said Plato. Yes.

### *Leakages*

A significant amount of water is lost in the water supply systems. Finding leakages is a very complex task. Over the years, different non-intrusive techniques have been used to monitor and identify the leaks. Some of these are visual techniques such as closed-circuit television, electromagnetic and radio frequency techniques (e.g. magnetic flux leakage, ground penetrating radars, acoustic and vibration techniques like sonars, vibro-acoustics), and other techniques such as infrared thermography and laser surveys.

Leakages are a major problem and can exceed 40% of the water produced, wasting money and energy.

### Example 17

Let's go back to Cape Clear Island "There is plenty of water. Why do we have to save?" as local co-op manager Máirtín O'Méalóid says, and answers himself: "Because of the leakages."

The pipework has been leaking heavily for over twenty years, due to large trucks and other heavy machinery being transported to the island, causing damage to the system. Old tanks were also leaking heavily, meaning there was reduced storage capacity.

Wells were being over-pumped in an effort to supply water to the system, although most of it was leaking out before it reached any house or business. Sometimes the water would be switched on at storage tanks but would be gone quickly because of a pipework failure due to the sudden pressure.

The island struggled to provide sufficient water during the summer months, water supply was switched off at night during the tourist season.

An investment of approximately 4.3 million euro will finally replace and rehabilitate 11.5 km of old water mains and other infrastructure on Cape Clear Island, resulting in the saving of an estimated 11 million litres of water per year on the island. It will also result in fewer burst mains, leaks, and disruptions to drinking water supply.

*For a view of Cape Clear Island, see Photo 21 on page 78*

## Wise governance

Water service management, organisation and financing build on different traditions and designs in different countries. In Europe, production and distribution of drinking water is mainly based on the fact that the principals have a full-cost charging system. However, many EU countries finance investments with municipal tax assets meaning the price of water services is not fully reflected by the price paid by consumers. Several countries are facing a revision of their systems and regulations due to the major challenges that climate change and extensive reinvestment needs entail.

An island's water saving abilities are partly a result of how its water services are managed, of how the use of rainwater and reuse of wastewater are stimulated, and of the price of water for households, hotels and industries.

## *Water management*

Of Europe's 2,160 islands, 1,920 are local communities without their own jurisdiction, 206 are municipalities, 32 are regions or states and 2 are countries. While mainland water management covers large drainage basins, islands are micro-systems where water is often scarce and it is hopelessly impossible to fit them into the big schemes.

These islands have 18.9 million all-year residents, 50 million summer residents and half a billion visitors. They consume approximately 6 million m3 of freshwater a year but produce 10 million m3 due to leakages. As the water needs on islands peak sharply in summer, much of the water is produced at a high cost, using lots of energy in reverse osmosis processes.

Some of the 1,920 non-municipal islands are managed from the mainland, ensuring high technical competence but not always with an understanding of the local conditions. Most of them manage themselves, with a certain lack of competence as well as resources, but with deep knowledge of the local circumstances.

Local water management on islands is of utmost importance. Water planning includes analyses of supply and demand, descriptions of existing facilities, and proposed construction programs. Although many master water plans do consider the potential effects of future conditions, recent advances in technology and changing social concerns are beginning to exert a significant influence on the future course of water system development. Some of the new considerations which should be incorporated into municipal water system planning include regulation on safe drinking water, coordination with wastewater planning, wastewater reclamation and reuse, environmental concerns, energy utilization, financial constraints, changing public attitudes – and of course, water saving.

### Example 18

In France, the management of water services is quite complex. Many of the country's municipalities are too small to manage and finance water supply themselves. Development and operation partnerships with private actors are common and can be organ-

ised in different ways. A private operator can have a long-term (20 years) responsibility for the entire water supply system, a type of privatization typically dating back to the mid-1800s. Still, the municipality has the ultimate responsibility towards its consumers, it owns the pipes and it is responsible for setting the water prices.
In addition to the 36,000 municipalities, there are three more levels of responsibility: ministries, regions and six "Agences de Bassin" which are a decentralized state representation. The state allocates some funds to the municipalities. The Ministry of the Environment issues special fees for water extraction, and the drinking water quality is controlled by the Ministry of Health.
The municipal water tax may only cover cost coverage within the fiscal year's water activities. The water fee consists of two parts: (1) a government-based amount designated for the different municipalities, plus (2) a variable consumption fee.
Special attention is paid to social corrections of the water tariffs where necessary. Although household water costs are quite reasonable in France (lower than in Germany, the Netherlands and Denmark), households with a low disposable income are eligible to receive a contribution for water (and electricity, gas and telephony).
On Houat, water issues are clearly and fairly controlled through the PLU (Plan Local d'Urbanisme), which stipulates that **all new buildings are to be built with a rainwater reservoir, and that swimming pools and private drills are prohibited**.
Houat actively cooperates with its neighbouring islands and the mainland, being a member of the island association "Les Îles du Ponant", the Auray Quiberon Terre Atlantique and the European Small Islands Federation. Water supply, treatment and storage is not managed locally but by the public drinking-water service company Eau de Morbihan Syndicat, SAUR (a French Urban and Rural Development Society established in 1933, specialized in the production and distribution of drinking water and wastewater treatment). Distribution is managed by Auray Quiberon Terre Atlantic community of communes, where the Mayor of Houat, madame Andrée Vielvoye, is also the chairwoman.

## ***Water price***

No single water tariff structure is trending. There is no magic bullet water managers can rely on. Increasing blocks, decreasing blocks, fixed charges versus variable charges, environmental charges - all these have different advantages and disadvantages around Europe. The most we can say is that the ideal tariff structure should seek to find a balance between the economic, environmental and social demands placed upon water resources and supplies.

### Example 19

The International Statistics for Water Services reports on "Total charges for Drinking Water for 165 Cities" (2016), showing the amount of fixed charge, variable charge, and other charges, adding up to total charge. Dublin is not there, why is that?

In Ireland, new water charges were introduced in January 2015, followed by huge protests. Irish Water, the utility set up to provide water services nationally, said that in the first billing cycle, only 44 percent were paying water charges. In the third billing cycle of 2016, 61 percent of their customers were paying – meaning 39 percent were not.

During 2016, the hot issue of water billing was entrusted to a committee which eventually issued a set of recommendations, basically that there will be no water charges for 92 percent of the households. Only a tiny fraction of the population will pay extra for water (i.e. households who are seen as water wasters and use more than 1.7 times the average amount). The average use in Ireland is defined as 345 litres per day for an average household of 2.6 people. That is 128 litres per person per day (l/p, d).

Households that use more than 589 litres of water a day (1.7 times the average amount) will be the ones who will be targeted for extra charges or levies. An estimation says there are 70,000 households in total in this bracket. There will be allowances for bigger families and those in exceptional circumstances who might pass the 589 litres figure earlier.

If water is free for residents up to 135 l/p, d, most people will not be engaged in saving water. On the other hand, businesses, who pay for water, will.

We are used to "economies of scale": the more we buy of a certain utility, the less we expect to pay since we know the production costs fall by numbers.

But what if we could turn this backwards to save water? What if we could use not only reverse osmosis but also reverse economies of scale? What if you pay less per $m^3$ if you use less water, by using **backwards billing**?

### Example 20

On Ithaka, which we visited during lecture 3, the demand for water was estimated at 247 million litres/year, where it is seems the islanders' use of rainwater meets one third of the demand. The total cost of extracting, producing, distributing and administrating water on Ithaka is 400,000 euro per year.

The cost is covered by billing the consumers 280,000 euro and by a 120,000-euro support from the Ministry, which is part of the Government's aid to islands who are off-grid and are forced to use desalination techniques.

The municipality has a brilliant backwards billing system: The less water you use, the less you pay per $m^3$. If a household uses 0-40 $m^3$ per 4 months, you pay 1 euro/$m^3$; if you use 41-80 $m^3$ per 4 months you pay 1.30 euro/$m^3$; if you use 81-120 $m^3$ per 4 months, the price is 1.50 euro/$m^3$; if you use 121-160 /$m^3$ per 4 months, the price is 2 euro/$m^3$; and finally, if you use more than 501 $m^3$ per 4 months you pay 3 euro/$m^3$.

The same goes for businesses (category 4, i.e. hotels) but with slightly different numbers and prices: if the hotel uses 0-150 $m^3$ per 4 months, they pay 2 euro/$m^3$; if they use 151-300 $m^3$ per 4 months, they pay 3 euro/$m^3$; if they use 301-500 $m^3$ per 4 months, the price is 15 euro/$m^3$; and if they use more than 501 $m^3$ per 4 months they pay 6 euro/$m^3$.

There is also a semi-professional category (3). If they use 0-50 $m^3$ per 4 months, they pay 1.60 euro/$m^3$; if they use 51-150 $m^3$ per 4 months they pay 2.00 euro/$m^3$; if they use 151-200 $m^3$ per 4 months, the price is 2.50 euro/$m^3$; if they use 201-250 $m^3$ per 4 months, the price is 3 euro/$m^3$; and finally, if they use more than 251 $m^3$ per 4 months they pay 5 euro/$m^3$.

Finally, hotels that "go green", meaning they meet a set of water-saving criteria as defined by a municipality board in 2009, pay a flat rate of 1 €/$m^3$ for water. An example of such a hotel is Nostos, which has a dual line for both tap water and well water so that it is possible to use slightly salty water from a garden well to flush the toilets in the hotel rooms but municipal water for the basins and the showers. Rainwater is used for the pool. The hotel guests praise the pool water and are happy like fish in the sea.

## *Turning off the water*

A radical measure is to turn off the water during the night or certain days of the week.

### Example 21

On Inis Oirr, the Tigh Ruairí (Strand House) Hotel cleverly gets water by three different means: (1) rainwater is collected from the roof via gutters and downpipes to a

3,000-litre tank buried in the garden. It is used to flush the toilets. (2) Two wells are in existance. One is 116 m deep, the other is 49 m, they are of very good quality, maybe a little high in ferrum. It is filtered with UV and pumped to two reservoirs, a steel one (15 $m^3$) and a smaller plastic one, and distributed by gravity to the hotel. This works 7 months a year, during "the wetter part of the year." (3) Imported water. Like the rest of the island, for 5 months a year it uses water from the main water pipeline.
Still, the girl in the hotel reception told us:
- "We have a scarcity of water. Please use it wisely. It will be closed off between 9 pm and 6 am."

### Example 22

Ithaka has three independent water networks: The Vathi-Perachori network, the Kioni network and the Stavros network. The latter is dependent on a desalination plant from 2005 which produces 200 $m^3$/d, pumped to a 100 $m^3$ reservoir in the Stavros village. In 2016, the plant produced 46,772 $m^3$. Since the water produced by the plant is not enough, the villagers **only have permission to water two days a week** (Mondays and Thursdays) from July 20 to September 15.

## ***Borkmanns Point***

Borkmanns Point is a crime novel by Swedish writer Håkan Nesser. The title of the work refers to a tipping point in the solving of crimes as proposed by chief inspector Borkmann, an admired senior colleague of detective Van Veeteren. Borkmann argues there is a point in an investigation where no more information is required. Having reached that point, a good detective knows enough to solve the case. All the evidence is there, fingerprints are secured, all the suspects and the witnesses have been interrogated, all the clues have been found. It is just a matter of understanding how it all fits together.
We have already given you a set of answers on how to save water. There are many more answers to water saving, there are many more questions to ask and there are many more people, organizations and institutions who can advise you. To name a few: European Structural and Investment Funds as well as specialized EU funds, the United Nations, with a library of best water practices, the Global Water Partnership, and the Stockholm International Water Institute. Find links to these and others on our website (*watersavingislands.eu*).
Eventually, you're at Borkmann's Point. Which leads us to the next lecture.

# The water saving challenge

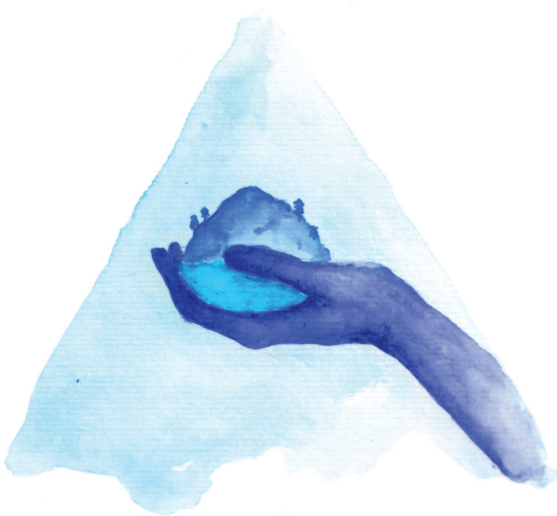
Water saving is a collective process to find suitable actions on a specific island. This process starts with (1) a challenge, a major, demanding task, and a fellowship to care for it. It continues with (2) raising funds, and (3) making research to get the facts right. With that in place, a (4) water-saving plan can be made, which is the central, middle step of the process. Then, (5) many hands need to be raised for the cause, there have to be some (6) quick fixes and (7) the changes have to take root. Saving water could be a big change on a small island, depending on the situation. Nevertheless, change is both a task and a process. The task is the hardware of change: technology, administration, financing – as described in lecture 4. The task is the technical dimension of water saving, what to do. The process is the software of change, what goes on between people: human interrelations, handling conflicts. The process is the social dimension of water saving, how to go about it, which we will deal with now in the fifth and last lecture.

## How to go about it

You need an open, inclusive process to handle your challenge. You need a good team, you need to have some funding, you need facts, you need to make a plan, you must get people on board, you must show some quick results to be convincing, and you must be sure changes will stick.

The challenge of water saving can be managed in seven consecutive steps:

## *Step 1 · The challenge*



Which comes first – the right cause or the right people? The team or the task? Impossible to say, but maybe in this case it is first "who" and then "what": get the right people on the bus, then figure out where to go.

You and your friends have this idea about saving water. Everybody knows the world is not the perfect place, everybody knows we use too much water, but is anyone going to do anything about it?

You have a sense of urgency for the issue of saving water. You need a challenging goal to get people off the couch, out of a bunker, ready to move – water saving should become important and urgent. You need a provocative yet attainable, defined objective. You have competence and friends around you and they are not just anybody. They want to make change happen and you want to start the process. Gradually, the team can grow.

### Example 23

From a previous project on the water situation on the Koster Islands in Sweden, from research on Malta, Greece, France and Sweden, and from our own, broad knowledge on small islands, we knew for certain most European islands could save much of the water they use. How much? We estimated any island could save 25 percent and made that our challenge.

Anyone can understand 25 percent is a lot. A lot of water, energy and money. Everyone reads the papers about the freshwater situation in the world which affects almost everyone today, right at their home. No one can turn down an offer to save 25 percent.

Our fellowship was an engaged politician: member of the European Parliament, a project manager, a professor with deep knowledge on freshwater, a researcher with a vast network of islanders and writing abilities, and a young student.

Eventually, the team grew as eight islands joined in, most of them represented by their mayors and water managers.

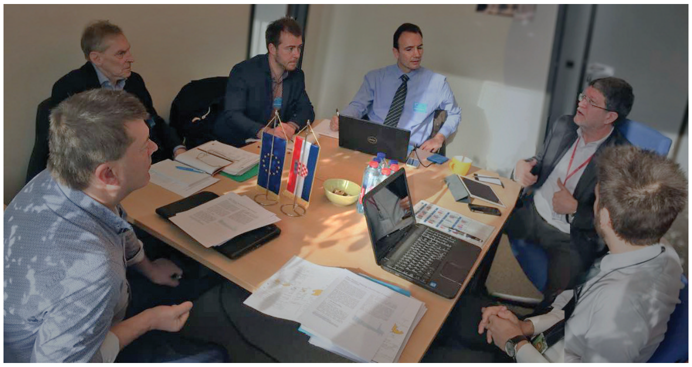
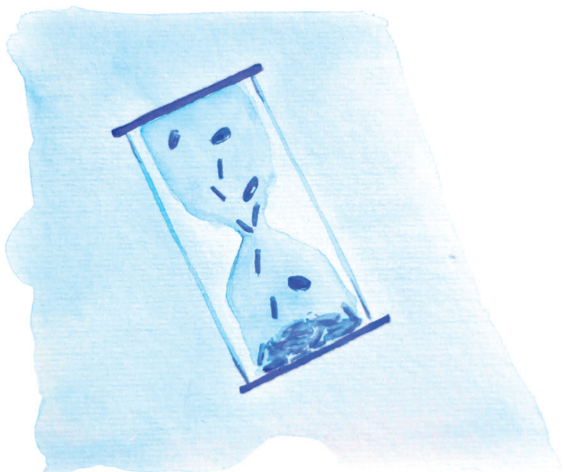


***Photo 19:*** *The core team behind the Water Saving Challenge project, from left to right: Mairtin O'Mealoid, Anders Nordström, Maxime Bredin, Christoforos Perakis, MEP Tonino Picula (S&D), Ivan Matić, and Christian Pleijel behind the camera.*

## *Step 2 · Raising funds*



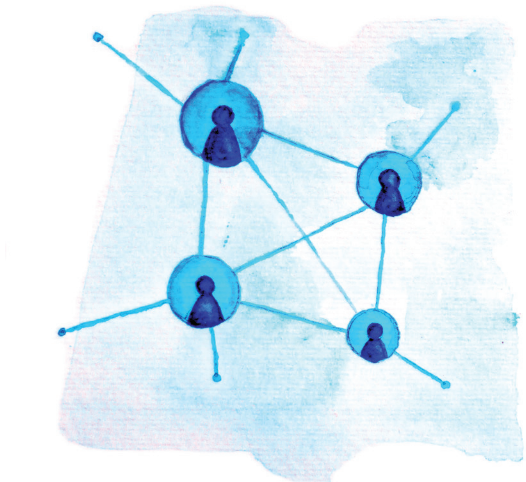
Which comes first – the right cause or the right people? The team or the task? Impossible to say, but maybe in this case it is first "who" and then "what": get the right people on the bus, then figure out where to go.

You and your friends have this idea about saving water. Everybody knows the world is not the perfect place, everybody knows we use too much water, but is anyone going to do anything about it?

You have a sense of urgency for the issue of saving water. You need a challenging goal to get people off the couch, out of a bunker, ready to move – water saving should become important and urgent. You need a provocative yet attainable, defined objective. You have competence and friends around you and they are not just anybody. They want to make change happen and you want to start the process. Gradually, the team can grow.

## *Step 3 · Finding the facts*

You need to examine the gut feeling you brought with you from step 1. You need to question yourself – and everybody else - who believe they know all about water. You need to research and verify you are on the right track. Water saving may be one of those cas-



es in which imagination is baffled by facts.
You have to get out of the office. Don't base your decisions on the advice of people who don't have to deal with the results. Talk to those who own the problems and the possibilities - the islanders.
Water saving is not only a monologue delivered by some expert in a rostrum. It is not only a roundtable dialogue between some powerful people. It has to be expanded into a demologue (demos is Greek for people, logos is speech) where all the inhabitants of an island engage in thinking, planning, acting and checking. The first part is field research, visiting places and meeting people.

### Example 24

In our project, we had eight islands to examine, understand and describe.
We made a field study on each of the islands. Our project manager, accompanied by a young researcher, met with hotel owners, farmers and school kids, checked wells and springs, inspected mains and pipes, pumping stations, RO plants, reservoirs, took pictures, studied maps and plans and statistics, met with the engineers and local administrators. We contacted researchers and consultants, visited the water office, asked and asked over again. The research team was in constant contact with our professor. We wanted to know the truth about the island's water assets, its use of water, and how it is produced and distributed. We wanted to describe the three layers of the islands as described in lecture 1, 2 and 3. We needed to build relations with the people responsible, we needed to build trust.

## *Step 4 · Making a plan*

When you believe you have seen everything, when you have the details that create the big picture, time has come to see if other people share the same picture. You need to set the scene for some serious creative thinking. You want people to have their own opinions,

but not their own facts. You want people to be part of a challenge, not a threat. You will need all the trust you have built so far.
The most important part of the plan is the planning. The heart of the matter is not the facts, the budget, the timeline, the technologies – it is the dialogue.
Without people believing in your cause, you will be lost.
Without people backing you up, there will be little water saved.
Without people joining your crusade, your efforts will be wasted.

**Example 25**

we gathered the core team, the mayors and the water managers we met during the field trips for a two-day workshop on one of the islands. During the workshop, we used Edward de Bono's *Six Thinking Hats*, the Schnelle brothers *Metaplan* (commonly called "post-its"), and Kauro Ishikawa's *Cause/Effect Chart* (usually named the "fishbone diagram").
The idea behind the six hats is to force people to see different aspects of a problem, to get alternative viewing angles to the water saving challenge.
The first hat is white and represent facts, and facts only. With the white hat on, everyone stays objective. What facts do we have about the actual water situation? What do we not know? With the white hat, there is no guessing and assuming, only precise numbers that everyone can accept. No feelings, no clues, no guesses, just checking the facts.
The next hat is yellow. It's the optimistic hat, searching for advantages, benefits and merits, without being emotional or appreciative. What could objectively be won by saving water?
The black hat stands for caution. Wearing the black hat, everyone is looking for reasons why it would not work. We are pessimistic, looking for apparent risks, being suspicious, watching out for mistakes.
The red hat gives you the right to be subjective, to talk about our feelings and to use our intuition. We could base our judgment on our inner beliefs, without being forced to motivate. "Yes, the numbers look good, but I still have the feeling that we've forgotten something." Under the red hat, it felt natural to talk about different cultures, identity, traditions and prejudices.

The green hat is used to find options, new directions, possibilities. This included some brainstorming. Had we not employed the white, yellow, black and red hat first, our creativity might have sprawled in many useless directions. The previous hats helped us stay focused, knowing what each of us knows and feels. The green hat makes us think about creating water saving options.
The last hat is the blue one. It is the chairman's hat, giving control over how the other hats are used and in what order. It organises, checks on time and summarises: "That's a good point of view but we take it under the red hat", "Now you've got your black hat on again, Mairtin", "What have we agreed on?" The blue hat is the one under which we decide what direction to go, how to move on. The blue hat is about choosing the best options and developing them into a plan.

All the work done under our workshop was documented with post-its organised in fishbone structures on big boards or on the walls of our meeting rooms. This made it easy for everyone to take active part in the process, and to understand what others had said and proposed.
These fishbone charts are the starting point, the creative sketches on which we will later develop more precise water saving plans.
We were lucky enough to have an external observer, a Swedish professor who observed us as part of her research on how to stage and navigate collective learning

https://www.kth.se/blogs/water/2017/11/water-scarcity-on-islands-how-to-stage-and-navigate-collective-learning/

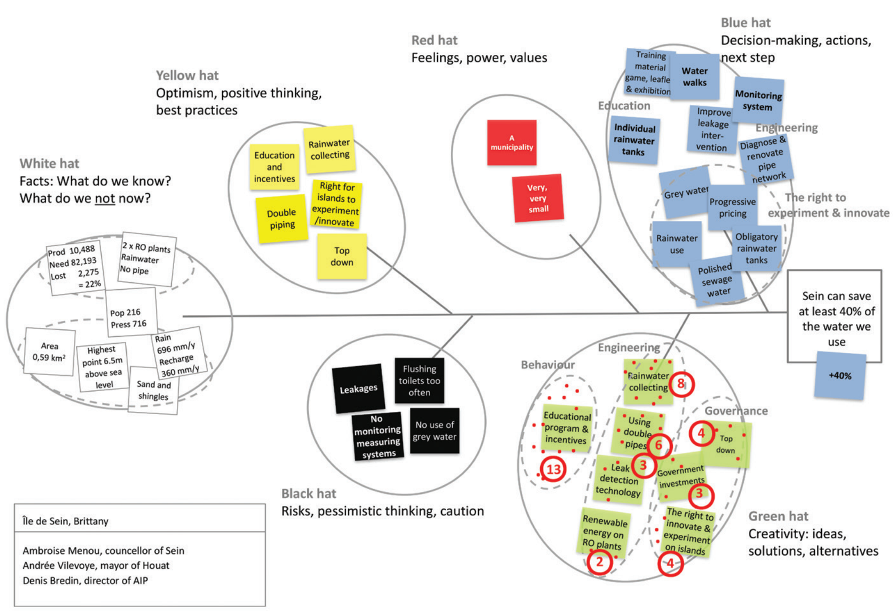



***Photo 20**: One of the "fishbones" (for Sein)*

## *Step 5 · Raising hands*

Now is the time to engage residents, visitors, managers, farmers, kids, teachers, officials and politicians. You need to talk, talk, talk.
Use all the channels you can to communicate the importance of water saving: informal meetings, meetings with the kids at school, meetings at the pub, at the shop, in the port, at the post office. Use social media, local newspapers, radio and posters. Remember: fighting water waste is a good, undisputable cause. Do not forget to talk, talk, talk.

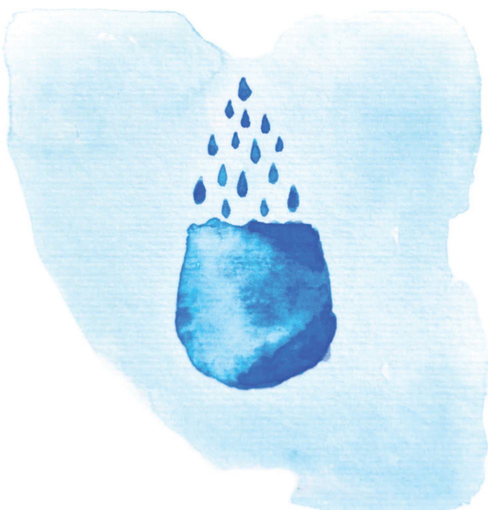
### Example 26

Samsø is a Danish island in the Kattegatt east of Jutland. Samsø is a municipality with 3,700 inhabitants and covers 114 km². Due to its central location, the island was an important meeting place during the Viking Age. In 1997, Samsø won a government competition to become a model for a renewable energy community and it is now producing 100 percent of its electricity from wind power and biomass.
Søren Hermansen, born on the island, was the guy who took on the competition. He had to convince his fellow islanders that their island could come to use 100-percent renewable energy. He knew the islanders were tight-knit and conservative, but he knew it could be an advantage: once he convinces enough potential first movers to act, the rest would follow. Hermansen showed up at every community or club meeting to give his pitch for going green. He pointed to the blustery island's untapped potential for wind power and the economic benefits of making Samsø energy-independent. And he sometimes brought free beer.
It worked. The islanders raised their hands in favour of Hermansen's ideas. They exchanged their oil-burning furnaces for centralized plants that burned leftover straw or wood chips to produce heat and hot water. They bought shares in new wind turbines, which generated the capital to build 11

large land-based turbines, enough to meet the entire island's electricity needs. Not being satisfied, they supported the construction of 10 massive offshore turbines, which provide power that offsets the island's dependence on cars and ferries. Today, Samsø isn't just carbon-neutral - it actually produces 10 percent more clean electricity than it uses, with the extra power fed back into the grid at a profit.

Hermansen has become a green oracle, traveling from country to country telling the story of Samsø's success when he's not at home running the Energy Academy, a research centre for clean power. But he's the first to say that the real credit belongs to the islanders, and that Samsø's lesson is that environmental change can only come from the ground up. Hermansen remarks: "People say: 'Think globally and act locally', but I say you have to think locally and act locally, and the rest will take care of itself."

## *Step 6 · Quick fixes*



You must walk the talk. Success is not just a big saving in the future, it is a small saving taken right now. Every project needs to show some short-term wins, small or big. They are needed to emotionally reward your comrades in the project, and to keep the critics at bay. Without visible, timely, unambiguous and meaningful wins, you will run into problems.

There are obvious successes that may be achieved cheaply and easily, what we call "low-hanging fruit". Even if they seem small compared with the challenge as a whole, they are evidence you are on the right track. Little drops of water make the mighty ocean. Do not underestimate the power of quick fixes and be sure to communicate them.

## ***Step 7 · Taking root***

Probably, the people of your island know a lot about water saving. How it's done, how it can be done. It's up to you to learn from them and from others. Three decades ago, Nobel Prize winner Wangari Maathai suggested to rural women in her native Kenya that they plant trees for firewood and to stop soil erosion. She said:
- "Until you dig a hole, you plant a tree, you water it and make it survive, you haven't done a thing. You are just talking."
Her trees took roots and her work grew into a nationwide movement to safeguard the environment, defend human rights and fight government injustice.
Sooner or later, your efforts to save water will run into the complex water regulations. Somewhere along the project, after the first easy wins, you will have to attack the sturdy defences and difficult politics of the old system. Eventually, you must choose to deal with these obstacles or you will never fulfil your challenge.

A very common source of inability to change is the formal arrangements often referred to as "The System". It can be laws, layers of hierarchy, rules, regulations and procedures, tying our hands when we want to help make a vision reality. In the public sector, bureaucracy is often such an obstacle. The way we reward people at work may also be an important holdback.
One way to break through is to work visually with simple tools such as the hats, the post-its and the fishbone diagram.
Another barrier is in our minds. We have all seen this: "No", says the water manager, "I have been running this water scheme for ten years now. I know what I am doing." Yet there is lots and lots to be done. Excursions and examples in this book might help. An example is not the main thing influencing others. It might be the only thing.
You must see to it that changes take root. If your plan balances the three types of actions – changing people's behavior, smart engineering and wise governance - in a consecutive process -chances are that change will stick.

***Photo 21**: Water taps at the antique well of Kalamos on Ithaka*

## Don’t run dry

We don’t want you to run dry, neither on water or on ideas. You have reached the end of the last of the five lectures. Congratulations and thank you for having stayed put.

In the beginning of our project and in the introduction to this book, we asked if it is possible to save water. We pointed out that we are not very theoretical, but we do hope we have given you enough theory to make you understand what could be done, enough practical guidance to get it done, and some good examples of how it has been done by other islands.

Can you save water?
Of course you can.

# Bibliography


Barthel, R., Banzhaf, S., Granberg, M., Pokorny, S. and Merisalu, J. (2018). *Grundvatten på Koster – status och framtida utveckling*. [online] Koster. Available at: https://www.kostershf.se

Bartley, P. (2015). *Groundwater Availability on the Aran Island of Inis Oírr in the context of providing a Sustainable Supply of Potable Water to the Island of Inis Oírr*. Report. Galway: Hydro-G

Brigand, L. and Barthon, C. (2002). *Les îles de Ponant: Histoires et géographie des îles et archipels de la Manche et de l'Atlantique*. Plomelin, France: Palatines.

Bäcker, A. (2016). "Proposal of water management solutions for Koster Islands" [Power Point Presentation]. *SustIsland* 2016.

Chiron, T. (2007). *Quel risque de pénurie d'eau sur les îles du Ponant?*. 202. [online] Norois, pp.73-86. Available at: http://journals.openedition.org/norois/1644.

Falkland, A. and Custodio, E. (1991). *Hydrology and water resources of small islands: a practical guide.* [online] Paris: UNESCO. Available at: http://unesdoc.unesco.org/images/0009/000904/090426eo.pdf

Hehir, P. (2014). *Alleviating Water Resource Problems Inis Oírr Island PWS - Case Study*. September. Galway: Galway School of Engineering.

Higgins, M. and Higgins, R. (1996). *A geological companion to Greece and the Aegean*. Ithaca, NY: Cornell University Press.

Hof, A. and Schmitt, T. (2011). *Urban and tourist land use patterns and water consumption: Evidence from Mallorca, Balearic Islands*. Land Use Policy, 28(4), pp.792-804.

Hynes, G. (2015). *Inis Oírr Water Audit Project. Water Conservation Recommendations*. Renergise.

Ironside Farrar Ltd. (2016). *Water and Land use Management Report*. September. Culemborg: ISLA Project.

Kapelj, J., Terzić, J., Kapelj, S. and Dolić, M. (2002). *Recent hydrogeologic study of the Vis island.* Geologija, 45(2), pp.419-426.

Kizos, T. (2007). *Island Lifestyles in the Aegean Islands, Greece: Heaven in Summer, Hell in Winter?.* Landscape Series, 7, pp.127-149.

Kossida, M., Kakava, A., Tekidou, A. and Mimikou, M. (2012). *Vulnerability to Water Scarcity and Drought in Europe*. Technical Report 3/2012. Prague: European Topic Centre on Inland, Coastal and Marine Waters.

Li, Z., Boyle, F. and Reynolds, A. (2010). *Rainwater harvesting and greywater treatment systems for domestic application in Ireland*. Desalination, 260(1-3), pp.1-8.

Nordström, A. (2005). *Dricksvatten för en hållbar utveckling*. Lund, Sweden: Studentlitteratur

Pleijel, C. (2015). *How to Read an Island*. Mariehamn, Finland: April Communication

Pleijel, C. (2017). *Kosteröarnas vatten- och avloppssystem*. Raport Alternativ 3. Projekt Koster VA

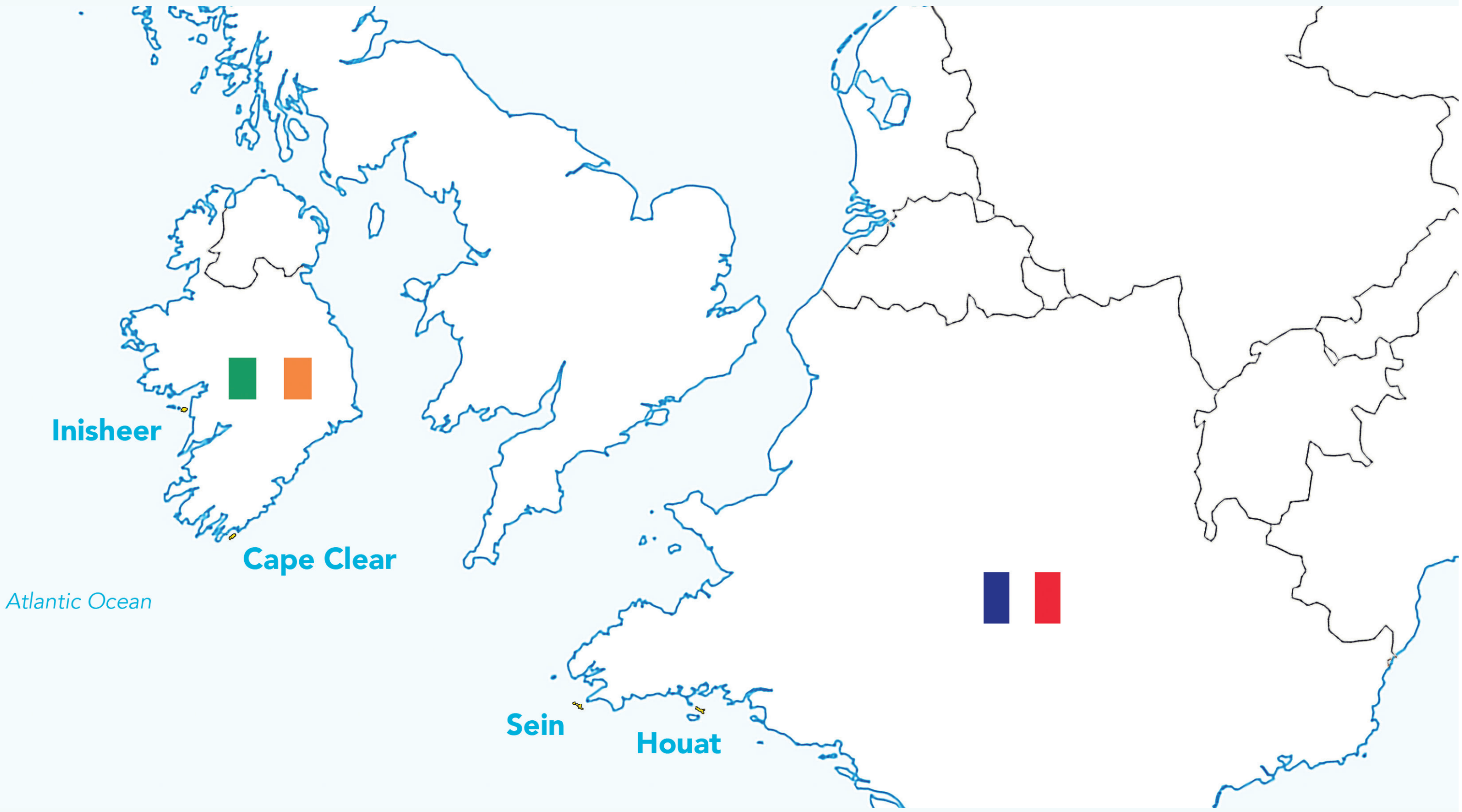
Spilanis, I. and Vayanni, H. (2003). *Sustainable Tourism: Utopia or Necessity? The Role of New Forms of Tourism in the Aegean Islands*. Journal of Sustainable Tourism, 00(0.2003), pp.1-23.

Starc, N. (2003). *Small Islands and Large Scale Spatial Development Patterns – Story of the Croatian Island of Unije*. In: 46th Congress of the European Regional Science Association. [online] Volos, Greece: European Regional Science Association. Available at: http://http://www.prd.uth.gr/ersa2006/

Grady, C. and Younos, T. (2014). *Potable Water*. Cham: Springer International Publishing.

Cover illustrations and "seven steps" illustrations in Lecture 5 are made by Iva Pezić.
Remaining figures are made by Christian Pleijel, with the exception of:

**1** Illustration 2: Groundwater in bedrock. Provided by professor Anders Nordström
**2** Cross section 1: Sustainable well usage. Provided by professor Anders Nordström
**3** Map 2: Hydro-G. 2015. Groundwater Recharge Map on the Aran Islands. From a Report Providing a Sustainable Supply of Potable Water to the island of Inis Oírr
**4** Cross section 2: Schematic hydrogeological map of the Vis Island. From: Janislav Kapelj, Josip Terzic, Sanja Kapelj and Mario Dolic. "Recent hydrogeologic study of the Vis island" (p. 423). From: Geologija, 45/2 (2002), pp 419-426
**5** Illustration 3: Typical rainwater scheme for an Irish house. From: Li, Z., Boyle F., Reynolds, A. "Rainwater harvesting and greywater treatment systems for domestic application in Ireland". From: Desalination, Volume 260 (2010), pp. 1-8
**6** Map 4: Overview of the Lastovo Water Supply Network. Provided by Lučijano Sangaleti, Municipality of Lastovo
**7** Photo 10: Water Usage Calculator. Available at: http://www.cbc.ca/pei/features/watercalculator/
**8** Photo 14: Kids outside Ghajn. Provided by the Energy and Water Agency, Malta
**9** Photo 15: WiCi. Available at: https://www.wici-concept.com


Inisheer
Cape Clear
Atlantic Ocean
Sein
Houat


***Map 5:*** Position of the eight islands involved in the project on the map of Europe