An Infra Free approach to improve the energy and resource management for illegal building settlements

Introduction

The development of the illegal building phenomenon in Italy

From the sixties of last century, growth of cities and small towns in Southern Italy has paid off the shortcomings of a very inadequate public housing program, which began late, often without an effective plan and characterized by a very long implementation time. This situation often caused lands assigned for various functions or services to be invaded and saturated by small scale buildings built by private citizens without a proper permission or with no permission at all.

In the course of the years the illegal building phenomenon development has been encouraged by the expectation of building amnesty laws that have been periodically issued by the central government since the eighties. This situation facilitated the setting up of a relationship net of mutual convenience in illegal building trade between developers, construction companies, local governments, central government, professionals, and often organized crime.

The illegal building phenomenon in peri-urban areas of small towns

In the case of small towns, the peri-urban sprawl of illegal residential houses has been tolerated and even implicitly encouraged by local governments which have been playing a role halfway between theoretical restrictions, settled by the central government and formal urban plans, and actual building activities put into action on territories. Strongly based on a political exchange, this implicit deal between local governments and private citizens leads the former to cover up and protect the latter's building abuses getting in exchange an effective social control on the community. On the other hand the central government tolerates this lawlessness situation because of a lack of public goods' production, but also because of a sort of calculation on the election consensus, as well as for a reasoning on the economic advantages coming from legalizing illegal buildings by building amnesty laws.

However, by the nineties in Italy there has been a strengthening of common environmental consciousness. The whole national territory has begun to be considered as an economic and environmental resource. This new position has given a value also to more conventional and ordinary landscapes, which were not usually recognized by legal system and even by urban planning culture or common sense. So the illegal building phenomenon in peri-urban areas has begun to be seen as an action giving an immediate benefit to private citizens by transforming and affecting the landscape, that is a collective good whose value is mainly assessed in the long term. European policies support this vision in the way they consider a badly constructed territory as a difficult object to be funded for requalification purposes.

Why is it necessary to improve illegal building settlements?

The previously described dynamics brought to the present situation of some territories, mostly in South Italy, affected by illegally constructed and then legalized buildings.

The Law 47/85 is the first act issued by the central government and it contains statements about the necessity to enhance the so called "illegal building settlements". The law provides rules, resulted from a long panel discussion, aiming both to control the territory in order to

prevent construction crimes and to draw informal settlements within the meshes of former planning tools, whose validity is thus confirmed.

The Case Study

The rural area of Giffoni Sei Casali (Region of Campania, Province of Salerno) is about 6 km^2, one sixth of the total municipal territory and represents an exemplary case of a peri-urban area deeply transformed by illegal construction of residential buildings. What's more, illegal buildings increased the hydro-geological risk which, in a large part of this territory, was already at levels ranging from medium to very high.
Anyway the site, a large flat area with hills in the background and delimited by two rivers on the eastern and western sides, remains very interesting from both a landscape point of view and for its peculiar land use characterization, testified by the presence of several family-run farms cultivating olive groves, vineyards, orchards (apple and pear trees) and hazelnut groves. Very important is also the cultivation of "cut salads" in greenhouses.
From the building point of view the area is characterized by a predominantly residential and agricultural use, with no recognizable urban definition. The recent illegal buildings, clustering in large settlements along the main roads or scattered on the rural land, have been constructed from scratch or were agricultural intended use buildings turned into residential ones. The most of illegal buildings in the peri-urban area of Giffoni Sei Casali have been legalized by amnesty laws issued in 1985, 1994 and 2003. As a consequence inhabitants living in former illegal buildings lay claim to services and urban quality level enhancement and the local government is the legal subject supposed to give them a response.

The Improvement Plan for the peri-urban area of Giffoni Sei Casali
Starting from the necessity to improve sites affected and transformed by illegal building activities, recently the local government decided to submit the entire peri-urban territory to a general plan review intended as an improvement plan aiming to enable a social, cultural and economic development and revitalization through protection of natural and cultural identity, enhancement of landscape and environmental resources, preservation of ecosystems and historical and cultural values.
In an innovative point of view, the new development plan intends to consider illegally built-up areas no more as accidents in local development's dynamics but as active subjects playing an important role in a synergistic action whose objective is to put into relation and balance environmental, economic-productive and social systems in order to overcome weaknesses and develop territorial potentials.

The establishment of an Agricultural Park as a strategy to enact the Improvement Plan
Given the high rural vocation of the site, the agricultural sector has been recognized as the matrix on which to structure a program designed both to protect and develop the peri-urban area: the rural system can produce proper and locally differentiated primary goods and, at the same time, can preserve and enhance territorial and environmental quality.
Starting from these assumptions the local government has proposed an Agricultural Park as a framework strategy on which to establish the whole improvement plan.
The proposed Agricultural Park intends to overcome the passive and ineffective aptitude of land preservation rules, proposing instead the goal of recovering the value of the rural area, with its capacity to resist soil consumption and its aptitude to be an active landscape builder.
The park, founding its action on on-site resources management to improve new economic

dynamics, could become an effective tool to recast a new balance and vital dialogue between settlement areas and agricultural production.

An Infra Free Pilot Project in the peri-urban area of Giffoni Sei Casali

In the strategic objectives' framework of the Agricultural Park proposed for the peri-urban area of Giffoni Sei Casali, the improvement project for illegal settlements should aim at getting maximum performances from conditions and potentials already existing on the territory and in the community.
Therefore, in order to be accepted by inhabitants and involve them into the enhancement process, an effective improvement project must comprise even inhabitants' selfish advantages, which are at the base of the birth and evolution of illegal buildings and now are expressed only in the strong demand for services and infrastructure, which are expected passively by inhabitants once they paid the sanctions to legalize what they built illegally.
At the same time, however, the action plan should be a breaking point with a vicious circle now leading to a growing territorial blight.

The Infra Free (Infrastructure Free) research

Infrastructures have had a fundamental role in the development of our economies. However this has happened at the cost of thinking of infrastructure net as the only and best solution to energy and resources supply, this way linking economic prosperity and life quality improvement of our societies to the implementation of centralized infrastructures. This means that, in a conventional point of view, peri-urban communities have small chances to enhance their life quality because of the difficulty of overlaying a rigid infrastructure net on a built environment characterized by buildings mostly scattered over the land.
What's more today our infrastructure are aged, are of high cost, and have repeatedly shown a range o weaknesses in a variety of disaster situations.
Starting from these assumptions the "Infra-Free" (Infrastructure Free) research, led by Prof. S. Anilir at the University of Tokyo, through the integration of many different disciplinary fields such as biology and aerospace technology, aims at contributing significantly to the development of the efficiency, flexibility and safety of future architecture by strengthening the synergy between technology and nature and reducing dependence on primary centralized infrastructure. The approach of IF research is based on the awareness that today technological innovation would allow modern buildings to be independent of infrastructure nets and consequently to be more flexible and capable to keep up with the fast changing demands of modern society to be in touch, stay in touch, work, live and relax. The innovation of the IF research relays upon its comprehensive point of view: relieving architecture of infrastructure framework's limitations can start a regenerative process involving all the aspects of future societies and leading to more sustainably living communities.
In this perspective architecture and building technology play an important part in the process with their capability to prefigure future scenarios and guide urban and society's development.

An Infra Free Pilot Project for the peri-urban area of Giffoni Sei Casali

In an Infra Free vision, lack or absence of infrastructure nets in peri-urban areas are no longer to be considered as a weakness but as an opportunity to rethink the energy and resource supply system in a flexible, improvable and more sustainable way.

Even the so typical building "incompleteness" of illegal settlements can be considered as a favourable condition for them to be completed and integrated by new technological components.
This perspective has led to reckon the illegal building settlements in the peri-urban area of Giffoni Sei Casali to be ideal testing grounds in which to establish an IF Pilot Project to experiment new and more self-reliant communities.
Shifting the focus from a conventionally designed improvement project, based on rigid models defined by urban planning's rules and common practice, to the choice of proper technologies and scenarios, the IF Pilot Project aims at enhancing inhabitants' life quality in a more sustainable way by stressing the potential of the territory and involving directly the "illegal community" in the improvement process appealing to their characteristic self-reliance will.

Selection and analysis of the Pilot Project's area

The Pilot Project's area, a foothill site of about 560,000 m^2, has been selected according to the features listed below which summarize the main characteristics and vulnerabilities of a typical peri-urban environment:

1. Absence or lack of infrastructure network such as sewage and methane gas networks;
2. Proximity of residential system and agricultural production system;
3. Presence of sites strongly characterized by ecological value such as riversides, streams, irrigation ditches, etc.;
4. Presence of small-scale illegal building clusters in which residential function is predominant in relation to other functions and activities.

Analysis of the Pilot Project's area

Land use data

The area is characterized by a strong agricultural vocation mostly testified by the presence of hazelnut cultivation, as shown in the table below.

Land use categories Pilot Project Area	Extension (m^2)	Percentage (%)
Water, rivers and streams	9,388	1.68%
Urban environment and artificial surfaces	59,820	10.68%
Hazelnut groves	257,353	45.96%
Orchards	61,776	11.03%
Natural and not cultivated areas	62,282	11.12%
Mixed and complex farming systems	109,392	19.53%
Total	**560,011**	**100.00%**

Tab. 1 - Land Use Analysis (source: Giffoni Sei Casali Municipal Office)

The land use analysis has been deepened for the category defined as "urban environment and artificial surfaces", representing almost 11% of the total Pilot Project's area.
Specifically the category "urban environment and artificial surfaces" has been divided into three sub-categories:

- Private Covered Areas;
- Not-paved private uncovered areas;
- Paved private uncovered areas.

This investigation aims at estimating the availability of areas in which to locate potential technological plants to improve the energy and resource management of illegal houses.
The table and the graph below summarize the data referring to the reformulated land use classification. Different agricultural lands are grouped in the single "agricultural areas" category. Water, rivers, streams and natural areas are grouped in the single "natural areas" category.

Land use categories Pilot Project Area	Extension (m^2)	Percentage (%)
Private Covered Areas	5,613	1,01%
Not-paved private uncovered areas	30,510	5.45%
Paved private uncovered areas	23,643	4.22%
Natural areas	62,282	11.12%
Agricultural areas	437,963	78.20%
Pilot Project total area	**560,011**	**100.00%**

Tab. 2 – Land Use Analysis (source: Giffoni Sei Casali Municipal Office; on site survey, April 2009)

According to this classification, the "agricultural areas" category is the widest one (78%) and each building owns an average uncovered area of about 1,350 m^2 of which 56% is unpaved and 44% is paved.

Building data

The total number of buildings in the Pilot Project's area amounts to 38 and the owners of 21 of these buildings have applied for legalizing their properties but it is not improbable that there are other unstated illegal buildings. The most of the buildings (31) are residential houses, mainly one or two-family detached houses. Some of them are agricultural storages (5), one is an inhabited rural building in ruins and one is a private box for vehicles.

In the analysis phase the residential building system has been divided into three groups according to their "Aggregation Typology":

1. Houses in settlement – several buildings related each to the other in a building cluster;
2. Single buildings – buildings near a building cluster but not directly related to it;
3. Isolated buildings – buildings not related to any urban or building context.

This distinction has been proposed in the analysis phase in order to consider proper intervention scenarios relating to building settlements' different mutual proximity and functional relation.
The table below shows the number and distribution of inhabitants per house aggregation typology.

House Aggregation Typology	Number of Inhabitants (n.)	Number of Buildings (n.)
Houses in Settlement	30	13
Single Houses	10	4
Isolated Houses	52	21
Total	**92**	**38**

Tab. 3 – House Aggregation Typology Analysis

In the area of the Pilot Project, more than half of residents lives in "isolated houses". It means that, since all the houses in the area of the Pilot Project are not connected to the sewage net,

the local government should provide houses, mostly scattered over a large rural land, with wastewater disposal and treatment and gas supply. In a conventional intervention plan, this kind of operations would heavily affect natural and agricultural environment and would be very expensive also considering that a large part of the Pilot Project's land is steep and uneven. Specifically for wastewater disposal and treatment the local government should construct two new main sewage pipes (at least 400-500 mm in diameter and more than 1,500 m long in total) along an existing irrigation ditch in order to allow all the inhabitants to gutter wastewater coming from their houses to the 10 km far away centralized wastewater treatment plant.

Though it is a condition not easy to verify because of inhabitants' reluctance to give information about their illegal situation, we can assert that at present some of the houses in the Pilot Project's area have no wastewater treatment and are discharging effluents directly into streams or ditches used in the past for irrigation purposes, causing water and ground pollution and hygienic problems. According to local government's evaluations the most of the houses are using "Imhoff" type septic tanks, performing a passive treatment and usually made up of circular or rectangular precast vibrated reinforced concrete components. "Imhoff" septic tanks are divided in two overlapping rooms: the upper one is for sedimentation; the bottom one is for sludge collection and digestion.

In Italy the law provides a regulation according to which an "Imhoff" tank performs only a primary treatment. This means that effluent from Imhoff tanks may never be discharged directly into a water surface, but it must be disposed on a dumping ground or drained into the subsoil.

Intervention scenarios

Converting the existing septic tanks into small-scale bio-digesters

In a first hypothesis it has been assumed that all the families living in the Pilot Project's area are using proper "Imhoff" septic tanks to treat wastewater coming from their houses. The size of the septic tank for each building has been estimated according to the dimension of each house and the number of inhabitants. The results of the evaluation show that a large part of the houses should treat their wastewater by using a more than 1 m^3 "Imhoff" septic tank.

Starting from this assumption, the research has evaluated an intervention scenario in which existing septic tanks are converted into bio-digesters in order to produce biogas from wastewater, kitchen waste and agricultural waste. Effluents from digesters and grey water from houses should be treated by constructed wetlands. Sludge from digesters should be used as a high-quality fertilizer for agricultural purposes.

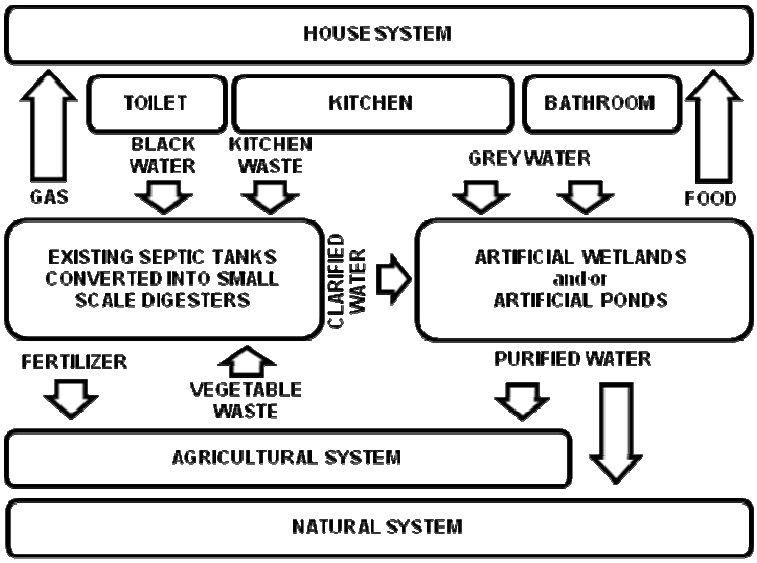


Fig. 1 – Intervention Scenario Scheme

Small scale anaerobic digestion and constructed wetlands are already largely used in some developed countries but the increasing cost of energy and resources is making researches and experimentations of these technologies more and more feasible also in the industrialized world.

Specifically for the Pilot Project's area the proposed scenario, starting from the necessity of treating wastewater, aims at involving directly the inhabitants into the enhancement process by giving them the opportunity to run low technological plants by themselves in order to produce some biogas for their needs. The utilization of agricultural waste, necessary to increase the biogas production to a satisfying level, could start a new relationship between house system and agricultural system based on mutual advantages: the former can treat wastewater and organic waste and can use the biogas production to cover part of their gas need; the latter can dispose for free of agricultural waste obtaining also fertilizer in exchange.

Constructed wetlands are demonstrated to be a very effective system to treat effluents from households and to have a big aptitude for biodiversity's improvement. Single houses can be provided with wastewater gardens (small scale constructed wetlands) planted in their not-paved private uncovered areas, treating grey water from houses and effluents from bio-digesters. Constructed wetlands along streams and riversides can treat effluents channeled from the houses in settlements and at the same time can be used as recreation places for inhabitants and/or to grow plants producing food for humans and animals.

The management of the enhancement process could be put directly into the hands of a consortium belonging to the Agricultural Park's board and gathering the inhabitants themselves and the operators of the agricultural sector. The local government would take an active role in guiding and stimulating the improvement process by limiting the bureaucracy and helping the relationship between the community living in the illegal settlements and the technical knowledge for the management of the technological systems.

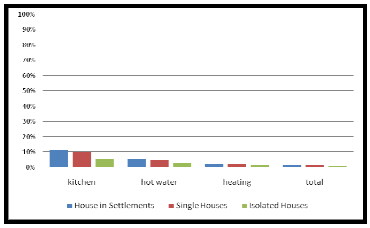
Evaluating the potential production of biogas

The tables and the graphs below show the results of the evaluation of biogas production per house aggregation typology by using a one phase "wet" process at a temperature ranging

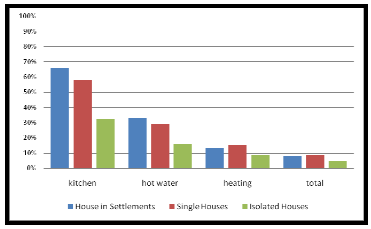
from 35°C to 37°C. The "wet" process has been the first evaluated one because of its low-technological level and consequently its lower cost. It uses biomass with 5% to 8% total solid content. This means that for substrates with a larger total solid content it is necessary to add water, this way increasing the needed bio-digester size. The biogas productions have been evaluated separately for each biomass. The evaluations are based on experimental data.

Type of biogas production process: WET					
House Aggregation Typology	**biogas from black-water**				
	total production	kitchen need coverage	hot water need coverage	heating need coverage	**total need coverage**
	m^3	%	%	%	**%**
House in Settlements	**0.33**	11.22%	561%	2.24%	**1.40%**
Single Houses	**0.10**	9.82%	4.91%	2.57%	**1.44%**
Isolated Houses	**0.27**	5.45%	2.72%	1.43%	**0.80%**
House Aggregation Typology	**biogas from kitchen waste**				
	total production	kitchen need coverage	hot water need coverage	heating need coverage	**total need coverage**
	m^3	%	%	%	**%**
House in Settlements	**1.92**	66.00%	33.00%	13.19%	**8.25%**
Single Houses	**0.56**	57.81%	28.91%	15.12%	**8.47%**
Isolated Houses	**1.62**	32.06%	16.03%	8.43%	**4.71%**
House Aggregation Typology	**biogas from vegetable waste**				
	total production	kitchen need coverage	hot water need coverage	heating need coverage	**total need coverage**
	m^3	%	%	%	**%**
House in Settlements	**1.89**	65.07%	32.53%	13.01%	**8.13%**
Single Houses	**0.55**	56.99%	28.50%	14.90%	**8.35%**
Isolated Houses	**1.62**	32.06%	16.03%	8.43%	**4.71%**

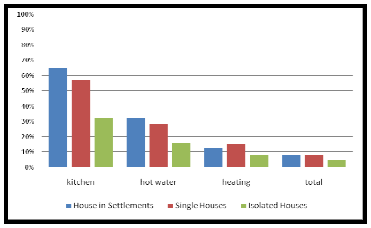
Active sludge



Kitchen waste



Vegetable waste



Tab. 4 – "Wet" Process: Biogas Production Evaluation

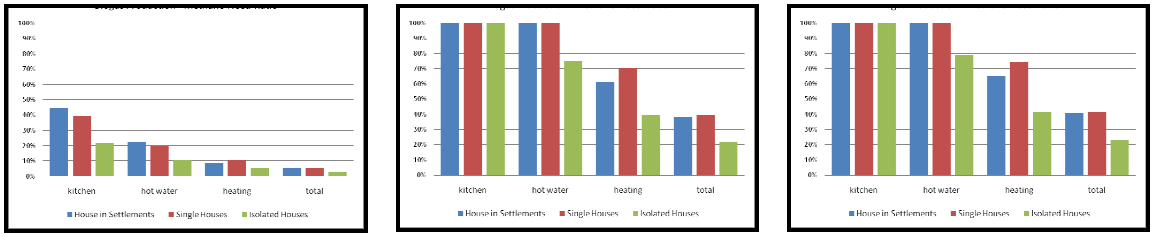
The most interesting result of this analysis is that a "wet" process applied to the digestion of kitchen waste could cover 66% of the gas need for cooking in the houses in settlements. But gas for kitchen rapresents only an average 14% of the total gas need of a house in the Pilot Project's area.

The results of a second hypothesis, in which biogas is produced by using a one phase "dry" process at a temperature ranging from 35°C to 37°C, are summarized in the tables and the graphs below. The "dry" process uses biomass with more than 20% total solid content. This

means that for substrates with a smaller total solid content it is necessary a pre-treatment in order to reduce the amount of water. Because of the high density of the substrates to be treated, the technological level is higher than the "wet" type, and consequently the management is more complex and the cost is higher too, but the needed bio-digester size is smaller. Also in this case the biomasses' productions have been evaluated separately. The evaluations are based on experimental data.

Type of biogas production process: DRY					
House Aggregation Typology	**biogas from black-water**				
	total production	kitchen need coverage	hot water need coverage	heating need coverage	**total need coverage**
	m^3	%	%	%	**%**
House in Settlements	**1.30**	44.87%	22.43%	8,97%	**5.61%**
Single Houses	**0.38**	39.30%	19.65%	10.28%	**5.76%**
Isolated Houses	**1.10**	21.79%	10.90%	5.73%	**3.20%**
House Aggregation Typology	**biogas from kitchen waste**				
	total production	kitchen need coverage	hot water need coverage	heating need coverage	**total need coverage**
	m^3	%	%	%	**%**
House in Settlements	**8.95**	308.00%	154.00%	61.57%	**38.49%**
Single Houses	**2.61**	269.78%	134.89%	70.54%	**39.53%**
Isolated Houses	**7.54**	149.59%	74.80%	39.32%	**21.99%**
House Aggregation Typology	**biogas from vegetable waste**				
	total production	kitchen need coverage	hot water need coverage	heating need coverage	**total need coverage**
	m^3	%	%	%	**%**
House in Settlements	**9.46**	325.35%	162.67%	65.04%	**40.66%**
Single Houses	**2.76**	284.97%	142.49%	74.51%	**41.76%**
Isolated Houses	**7.96**	158.01%	79.01%	41.54%	**23.22%**

Active sludge **Kitchen waste** **Vegetable waste**



Tab. 5 – "Dry" Process: Biogas Production Evaluation

The results of the analysis are more interesting than the ones resulted from the "wet" process and show that kitchen waste and vegetable waste are enough to cover kitchen and hot water needs. In the case of the houses in settlements it could be possible to connect the bio-digesters each to the other in order to increase the efficiency and to prevent lacks in the biogas production of a single household.

Economic feasibility

Since the research is still in progress until now it has been possible to estimate roughly how much money each household could save by using the proposed system integrated with a conventional energy resource supply. In a further step the research will evaluate the cost of converting the existing septic tanks into small scale bio-digesters suitable to the specific needs of the residents, the costs of installation, management and maintenance of the proposed technologies and the amount of money that inhabitants and local government can save by sparing waste collection and disposal systems and infrastructure nets.

Estimating energy and resource costs

In order to evaluate the energy cost for kitchen, hot water and heating, the research has estimated firstly the energy need per each household. The results, summarized per house aggregation typology, are listed in the table below.

House Aggregation Typology	Kitchen Energy (MJ/year)	Hot Water Energy (MJ/year)	Heating Energy (MJ/year)	Total Energy (MJ/year)
Houses in Settlement	42,390	84,780	212,058	**339,228**
Single Houses	14,130	28,260	54,039	**964,29**
Isolated Houses	73,476	146,952	279,519	**499,947**
Total	**339,228**	**96,429**	**499,947**	**935,605**

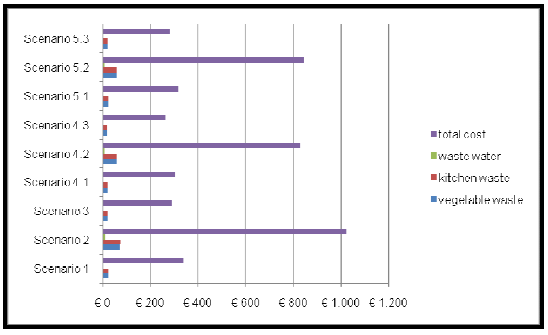
Starting from these data the research has evaluated and compared the costs of different conventional energy resource supply scenarios that could be used by the inhabitants of the Pilot Project's area to cover their energy needs:

Scenario 1 - All the households are using methane gas;
Scenario 2 - All the households are using gasoline;
Scenario 3 - All the households are using LPG;
Scenario 4.1 - All the households are using methane gas (70%) and wood (30%);
Scenario 4.2 - All the households are using gasoline (70%) and wood (30%);
Scenario 4.3 - All the households are using LPG (70%) and wood (30%);
Scenario 5.1 - All the households are using methane gas (70%) and pellet (30%);
Scenario 5.2 - All the households are using gasoline (70%) and pellet (30%);
Scenario 5.3 - All the households are using LPG (70%) and pellet (30%);

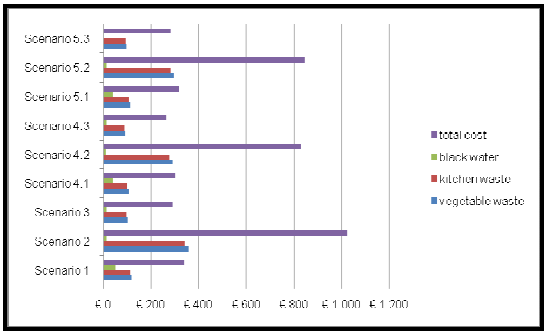
The table and the graphs below show the possible average money savings per each household in the different energy resource supply scenarios by using small scale bio-digesters treating the biomasses in the two different "wet" and "dry" processes evaluated before.

	Average Total Cost	Money saving by using a "wet" process			Money saving by using a "dry" process		
		black water	kitchen waste	vegetable waste	black water	kitchen waste	vegetable waste
	(€/year)	(€/year)	(€/year)	(€/year)	(€/year)	(€/year)	(€/year)
Scenario 1	338	4	24	24	16	113	119
Scenario 2	1,023	12	73	72	50	341	360
Scenario 3	293	4	21	21	14	98	103
Scenario 4.1	302	4	22	21	15	101	107
Scenario 4.2	831	10	59	59	40	277	293
Scenario 4.3	266	3	19	19	13	89	94
Scenario 5.1	319	4	23	23	15	106	112
Scenario 5.2	847	10	61	60	41	282	298
Scenario 5.3	282	3	20	20	14	94	99

"Wet" process



"Dry" process



Tab. 6 – Comparison between Energy Resource Supply Scenarios

The results of this analysis are extremely interesting also considering that experiences already conducted show how it is possible to increase the biogas production efficiency by mixing wastewater, kitchen waste and vegetable waste substrates.
For example in the "Aquanova" project the researchers of the IMAGE Department of the University of Padova have installed an experimental bio-digester system in a mountain shelter in Italy. To feed the system the wastewater is previously reduced and separated into brown water and yellow water by using special toilets and then mixed in the most effective percentages (according to experimental tests conducted in laboratory) together whit organic waste. The system itself is quite complex but at the end it can produce enough biogas to cover completely the kitchen need of the shelter and the energy consumption of the system itself.

Further steps of the research

The effectiveness of the project proposed in this research relays on the strong necessity to solve important problems of residents such as treatment of domestic wastewater without affecting the territory already deeply transformed by illegal building activities.
Designing a project strongly based on residents' individual advantages, such as reduction of costs of energy and waste disposal, is a strategy to have the project itself accepted by inhabitants who, otherwise, would claim for more conventional and invasive solutions.

The promotion of a waste recycling system to improve the relation between house settlements, agricultural production and nature aims at reducing energy and raw material consumption by making people aware and more respectful of the potentials of the territory they inhabit.

Until now the research has been evaluating the feasibility of the Infra-Free Pilot Project. In a further step the research aims at starting a collaboration between university, local government and private companies in order to establish a real laboratory in the former illegal settlements in the peri-urban area of Giffoni Sei Casali in which to experiment regenerative processes leading to more sustainable communities.
In this vision the presented research can be considered as a first step of an enhancing process starting form low-tech solutions but aiming at integrating the peri-urban territory with more and more effective technological components.

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