12/04/2021

Regions and Municipalities for a Just Transition

Sustainable District Heating Solutions for Western Macedonia

LDK Consultants

WWF

European Climate Initiative EUKI

Final Report

Source: UNEP – Unlocking the potential of Energy Efficiency and Renewables







Contents

1. Introduction

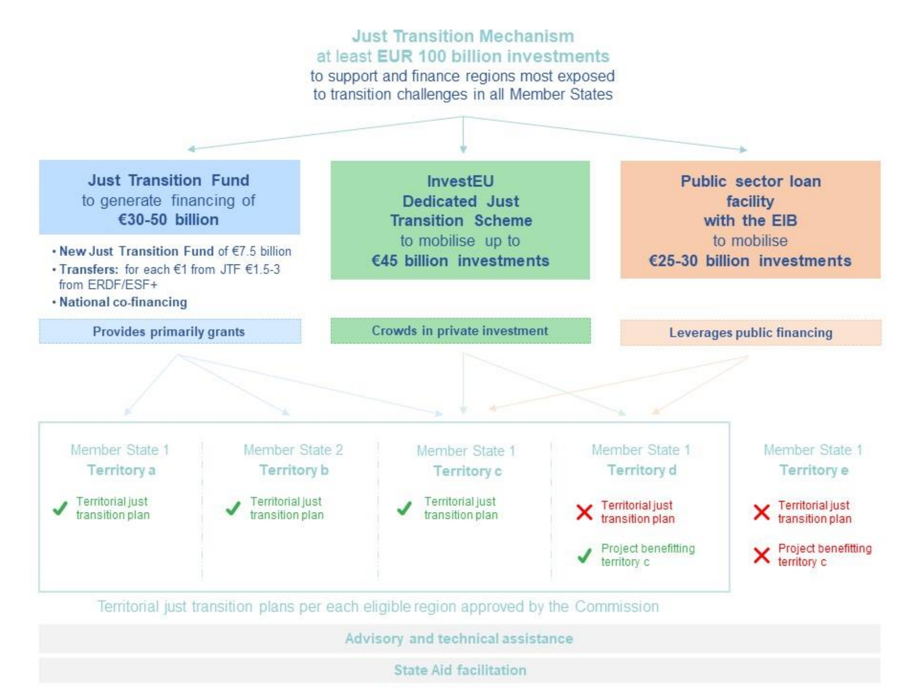
Policy Framework

Under The Green Deal Financing Mechanism

To ensure that the transition happens in a fair way, the Commission set up a Just Transition Mechanism, with the aim to provide targeted support to MSs, regions, businesses and workers most affected.

This Just Transition Mechanism is structured around three pillars of financing:

- **Just Transition Fund:** Primarily grants to regions where many people work in coal, lignite, oil shale and peat production or to regions that host GHG-intensive industries. It will also support investments in clean energy transition (e.g. Energy Efficiency).
- **InvestEU Fund:** Aims to attract private investments that benefit those regions and help their economies to find new sources of growth. For example, projects for decarbonization, economic diversification, energy, transport and social infrastructure.
- **EIB Loan Facility:** Will be used for concessional loans to the public sector, for investments in energy and transport infrastructure, DH networks, and renovation of buildings.



Source: *EC (2020) Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Sustainable Europe Investment Plan - European Green Deal Investment Plan*. Brussels 14.1.2020

The three financing pillars are tied together by “Territorial Just Transition Plans”. Territories receiving support from the Just Transition Fund will also benefit from a dedicated technical assistance facility to be set up at the initiative of the Commission.

Technical assistance and advisory support at all levels of public administration will help to identify and prepare sustainable projects and provide capacity building to project promoters through the Structural Reform Support Programme which will provide technical support to MSs to help design and implement growth-enhancing reforms.

Project Rationale

Objective

A realistic assessment of **reliable, efficient and economically viable green alternatives for the district heating systems in Western Macedonia,** that could support the wider region as well as the employment potential of those solutions in the immediate aftermath of coal plants and mines decommissioning, compared to the baseline scenario which are based on natural gas.

Methodology

- **Task 1: Assessment of the current and future/projected state-of-play**
  - Preliminary trend forecasting of the regional DH market development
  - Delineation of the DH energy infrastructure investment roadmap
  - Development of the baseline future scenario

- **Task 2: Identification of the green district heating solutions palette for W. Macedonia**
  - Identification of technically applicable green alternative DH solutions
  - Assessment of key baseline indicators
  - Sustainable share of heat demand per solution
  - Preliminary techno-economic analysis per solution

Project Rationale

Methodology

- **Task 3: Sustainable roadmap**
  - Selection of technologies to be incorporated in the alternative sustainable mix
  - Definition of boundaries for technologies
  - Multicriteria analysis with technical and socio-economic factors
  - Shortlist of key scenarios
  - Optimum green alternative DH solutions
  - Roadmap of deployment
  - Financing and other key issues

2. State of Play in Western Macedonia

District Heating Systems in W. Macedonia: Evolution & Prospects

Baseline Scenario

According the National "Just Transition Development Plan of lignite areas", the plan to ensure district heating envisages the creation of a thermal hub in Western Macedonia which will consist of:

- **Modified unit of Ptolemaida V**
  Installed Capacity: 140MW$_{th}$
  Estimated annual production: 300-400 GWh/year
  Expected to be operational in the first half of 2022 | Base load PP
- **New High Efficiency CHP unit in Kardia**
  Installed Capacity: 60MW$_{th}$
  Estimated annual production: 270-350 GWh/year
  Expected by 2023
- **Electric boiler**
  Installed Capacity: 80MW$_{th}$
  Estimated annual production: 10-125k MWh/year
  Expected to be operational in the second half of 2021 | Initially a Base load PP - Peak load PP from 2022 onwards
- **Gas boiler**
  Installed Capacity: 100MW$_{th}$
  Estimated annual production: 10-125 GWh/year
  Expected by 2023

In the transitional period for Western Macedonia the district heating will be provided through the **interconnection of Amyntaio, Ptolemaida and Kozani with a network of hot water pipes**

Total Planned:

- Installed Thermal Capacity: 380 MW$_{th}$
- Estimated Annual Production: 600 - 1,000 GWh$_{th}$/yr

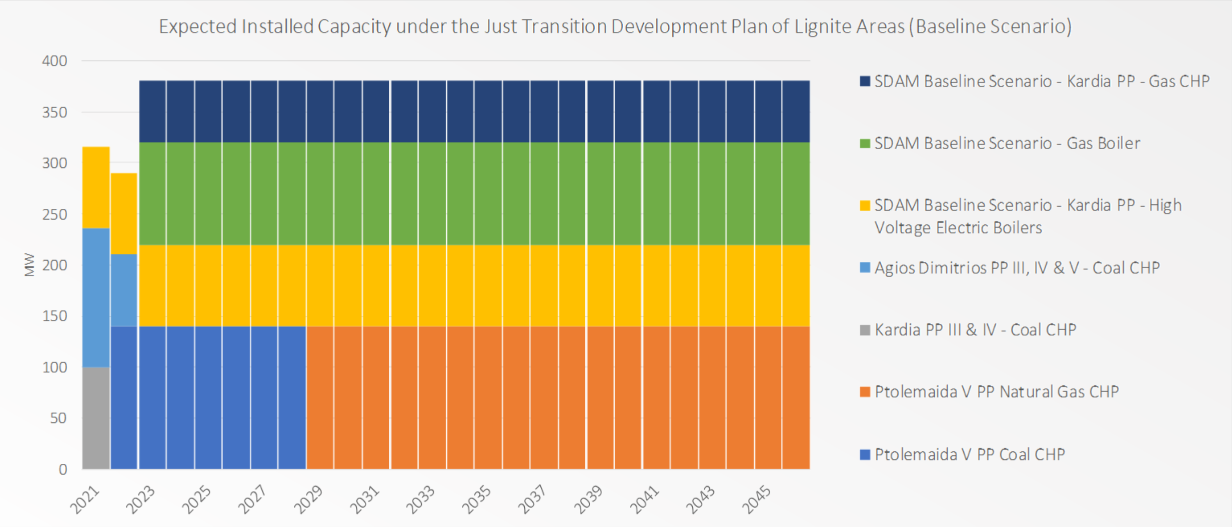
District Heating Systems in W. Macedonia: Evolution & Prospects

Present Situation

The following depict the present situation of the DH market in W. Macedonia, based on published material, data received from local district heating companies and the “Just Transition Development Plan of Lignite Areas”.

SN	District Name	Nominal Capacity [MWth]	Thermal Storage Volume [m3]	Capacity [MWth]	Network Length [km]	Connections Number	Buildings Number	Consumption [GWh/yr]	Tariff [€/MWh]
1	Kozani	220	3300	187	454	29000	5543	276	43.50
2	Ptolemaida	105	3800	215	290	15575	4000	220	37.74
3	Amynteo	30			175	2000		33	56.50
4	Florina	113	-	-	80	2534	-	-	-

Weighted 40.9 €/MWh



District Heating Systems in W. Macedonia: Evolution & Prospects

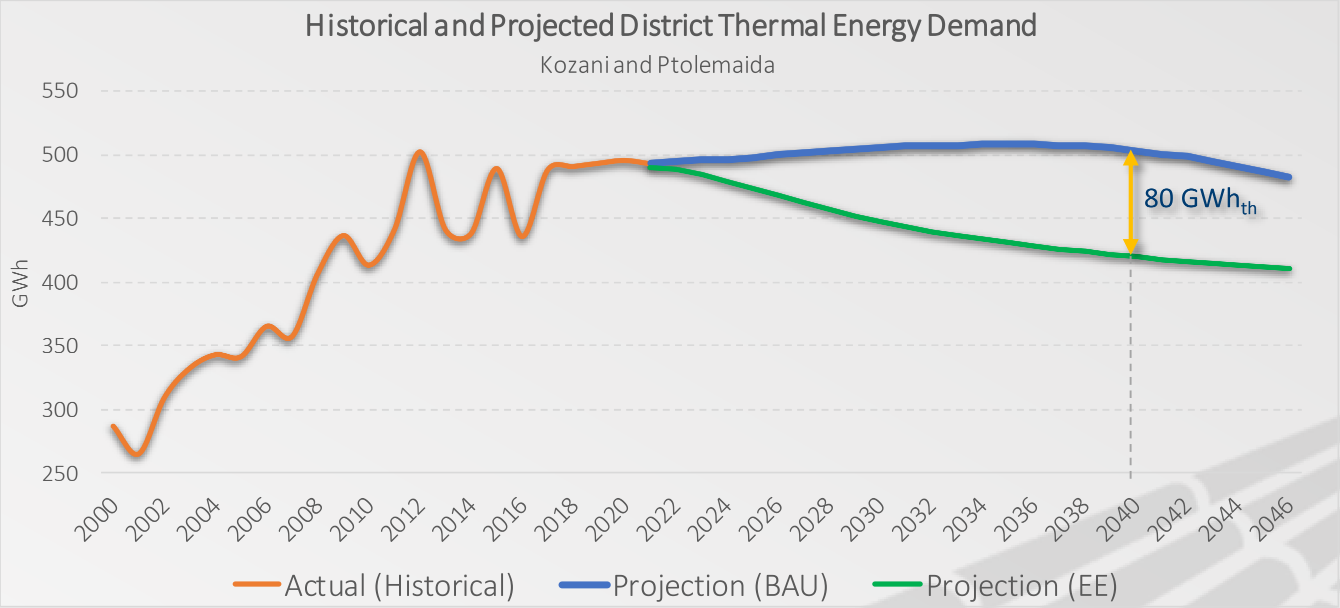
Projected heat demand

According to published data concerning the results of the recent EE NSRF programme in Greece:

- A budget of 73.5 m€ will be directed to EE renovations of residential buildings in W. Macedonia
- Average budget of ca. 25,000 €/residence →
- Total of 3,000 buildings in W. Macedonia

Relevant indicators based on relevant LDK work:

- Indicator for **thermal** EE renovations for residential buildings (Savings/CAPEX): 1.1 GWh_{th}/m€ → 80 GWh_{th} estimated overall savings for W. Macedonia
- Assuming just 5% of the above budget (<4 m€/year) directed yearly to the DH buildings of WM lignite regions → Savings of 4 GWh_{th}/year → Savings of 80 GWh_{th} till 2040

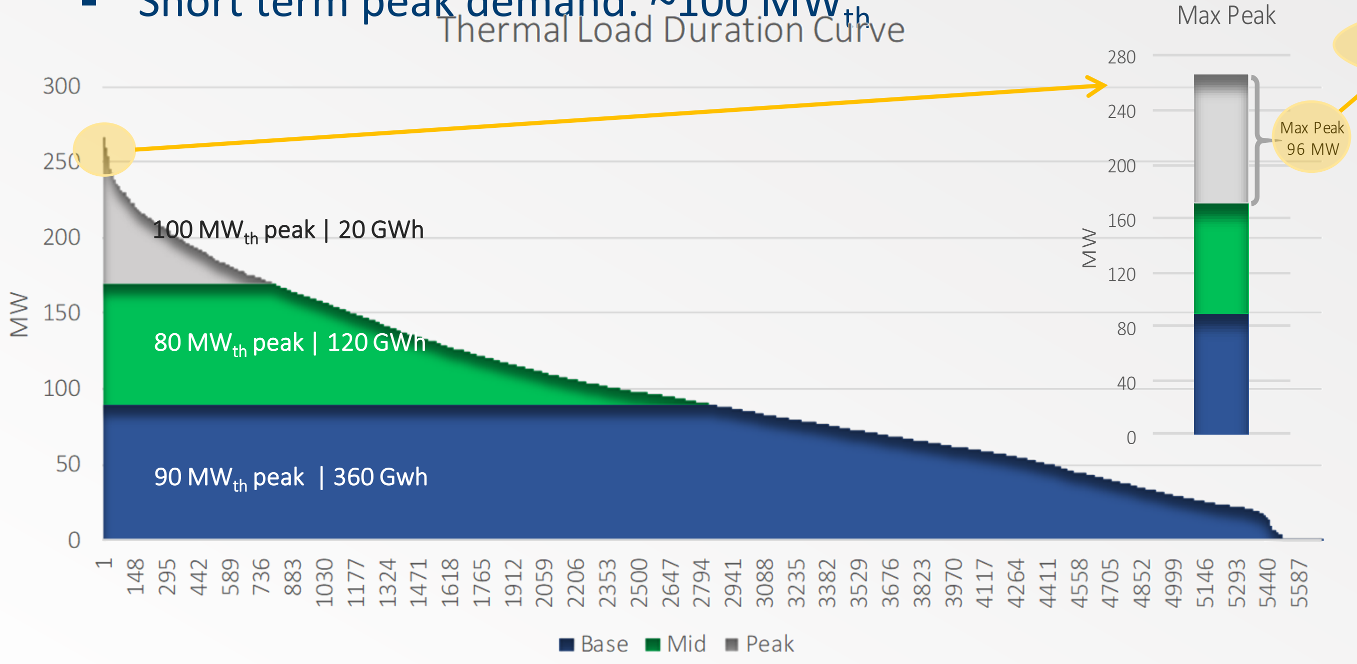


District Heating Systems in W. Macedonia: Evolution & Prospects

Full load hours

Kozani and Ptolemaida districts will be subject of analysis:

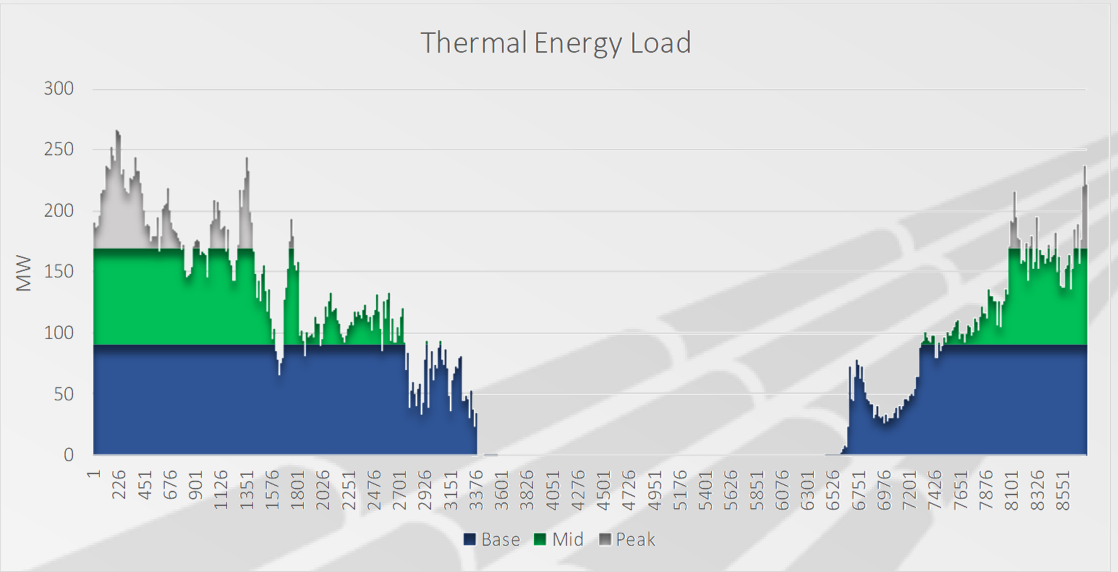
- Total annual thermal energy demand: ~500 GWh
- Maximum thermal capacity (peak): ~270 MW_{th}
- Short term peak demand: ~100 MW_{th}



Notes

- ❑ Amynteo DH system is assumed to be covered by the biomass boiler
- ❑ Florina DH is not yet constructed and not be covered within the techno-economic analysis of this study

Demand for a flexible DH system including Thermal Energy Storage



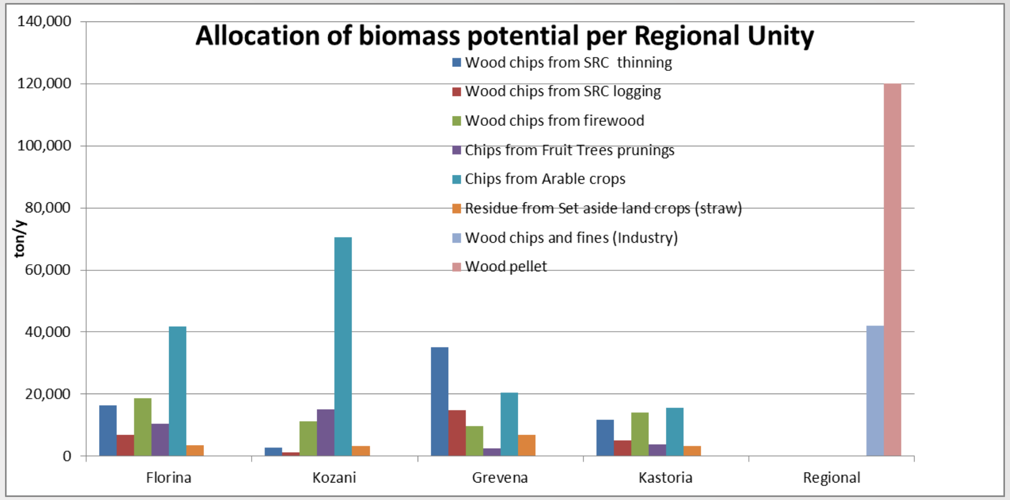
3. Green District heating solutions palette

1. Biomass Boiler

Biomass potential

Currently the biomass market in Greece is immature. There is significant sustainable biomass potential in the wider region from various sources. However, exploitation would demand sophisticated supply chain. Thus, dependence in biomass involves substantial degree of risk.

However, the recently operational biomass boiler plant of 30MW in Amynteo is expected to encourage the biomass market related businesses and activities and facilitate the creation of a broader regional supply chain.



Source: LDK work

Maximum biomass potential based on research of similar previous projects in the region

	Tonnes / year		
	Florina	Kozani	Total
Wood chips from SRC thinning	16,485	2,838	19,323
Wood chips from SRP logging	6,912	1,192	8,104
Wood chips from firewood from Public + Non Public Forests logging	18,749	11,129	29,878
Wood chips from Fruit Trees prunings	10,348	15,016	25,364
Wood chips from Arable crops residue	41,717	70,566	112,283
Residue from Set aside land crops (straw)	3,492	3,171	6,663
Total	**97,703**	**103,912**	**201,615**

It is considered that such large quantities are unlikely to be recovered. According to the most optimistic estimates, actual figures range below 100,000 tn/yr.

According to recent figures Amynteo's 30MW Biomass plant demand is estimated at 15,000 tn/yr

1. Biomass Boiler

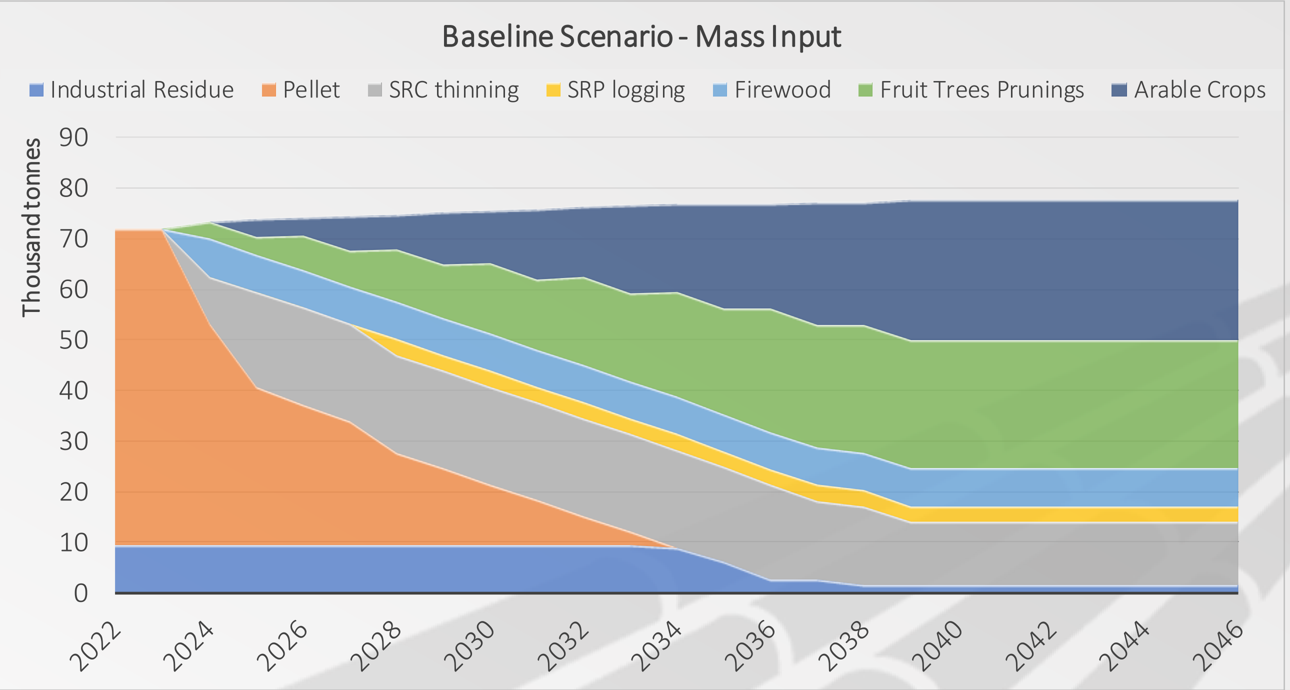
Key technical features

The assumed baseline case represents a biomass plant that can cover 60% of the total heat demand of Kozani-Ptolemaida DH systems. The plant correspond to a boiler of **94 MWth. Assuming a gradually evolving deployment of biomass sources and** average maturity rate for the supply chain system the ultimate balance of sources utilization consisting primarily of arable crops and fruit tree prunings takes effect after 15 years whereas during the first years of operation pellets and industrial wood residues are used in larger extent.

*Calculations for a **94 MW$_{th}$** biomass boiler plant*

Biomass Boiler		
Max Local Biomass Potential	821,018	MWh/y
Annualy Recoverable Potential	40	%
Annualy Recoverable Potential	330,391	MWh/y
Annualy Recoverable Potential	76,051	tn/y
Thermal plant capacity	94	MW
Average Plant Efficiency	90	%
Operation period	3,500	h/y
Thermal energy to DH	297	GWh/y

The Baseline Scenario represents more dependence on biomass from wood processing industry and pellets (and consequently additional biomass costs) in the short term (first 3 years), while in the long-term it is assumed gradual development and maturity of the regional supply chain until full supply from agricultural residues.



1. Biomass Boiler

Assumptions

Energy Content and Specific costs of feedstock

Fuel Type	RH	HHV (dry)	HHV	Quantity	Price	Energy	Specific cost
	%	kcal/kg	kcal/kg	RH 5%	€/ton	MWh/tn	€/MWh
Wood chips and fines (residue from wood processing Industry)	25%	4,800	3,600	0.80	80	4.2	19.1
Wood pellet (certified product from woodfuel Industry)	7%	4,300	3,999	0.98	130	4.7	28.0
Wood chips from SRC thinning	20%	4,300	4,000	0.85	40	4.7	8.6
Wood chips from SRP logging	20%	4,300	4,000	0.85	40	4.7	8.6
Wood chips from firewood from Public + Non Public Forests logging	25%	4,500	3,375	0.80	60	3.9	15.3
Wood chips from Fruit Trees prunings	25%	4,800	3,600	0.80	30	4.2	7.2
Wood chips from Arable crops residue	25%	4,800	3,600	0.80	30	4.2	7.2
Residue from Set aside land crops (straw)	25%	4,300	4,000	0.80	80	4.7	17.2

Biomass Boiler – CAPEX and OPEX Indicators

CAPEX	300	**€/kWth**
OPEX	169	**€/kWth**
Variable	25	*€/kWth*
Fixed	6	*€/kWth*
Electricity Cost	14	*€/kWth*
Biomass Cost	40	*€/kWth*
Total	85	*€/kWth*

Supply chain

- Network of satellite stations in appropriate geographical locations and at appropriate distances from the plant is recommended.
- This will ensure the security of supply of biomass and the establishment of a local trade channel with agricultural characteristics

1. Biomass Boiler

Key Results

- **Capacity:** 94 MWth
- **Heat production:** 330 GWh/y
- **CAPEX:** 28 MEUR
- **Weighted DH tariff:** 41 EUR/MWh
- **Simple payback:** 6.8 years
- **IRR:** 8.3 %
- **LCOE:** 39 EUR/MWh

Lifecycle analysis performed for 25 years

Green DH Solution 1

Biomass Boiler

Key Input data

Description	Unit	Cost/ Benefit
Income from electricity	EUR	0
Income from thermal energy	EUR	12,174,475
Total income	**EUR**	**12,174,475**
O&M costs	EUR	-2,913,465
Electricity costs	EUR	-1,321,563
Total O&M	EUR	-4,235,027
Biomass costs	EUR	-3,761,227
Inflation	%	0%
Project Lifetime	years	25
Tax Rate	%	0
Discount Rate	%	10%
CAPEX	EUR	28,319,200

Results

Description	Unit	Value
Net Present Value (NPV)	EUR	**-5,386,849**
Pay-Back Period	years	6.8
Benefit Cost Ratio (BCR)	-	0.8
LCOE	€/MWh	39.0
Internal Rate of Return (IRR)	%	**8.30%**

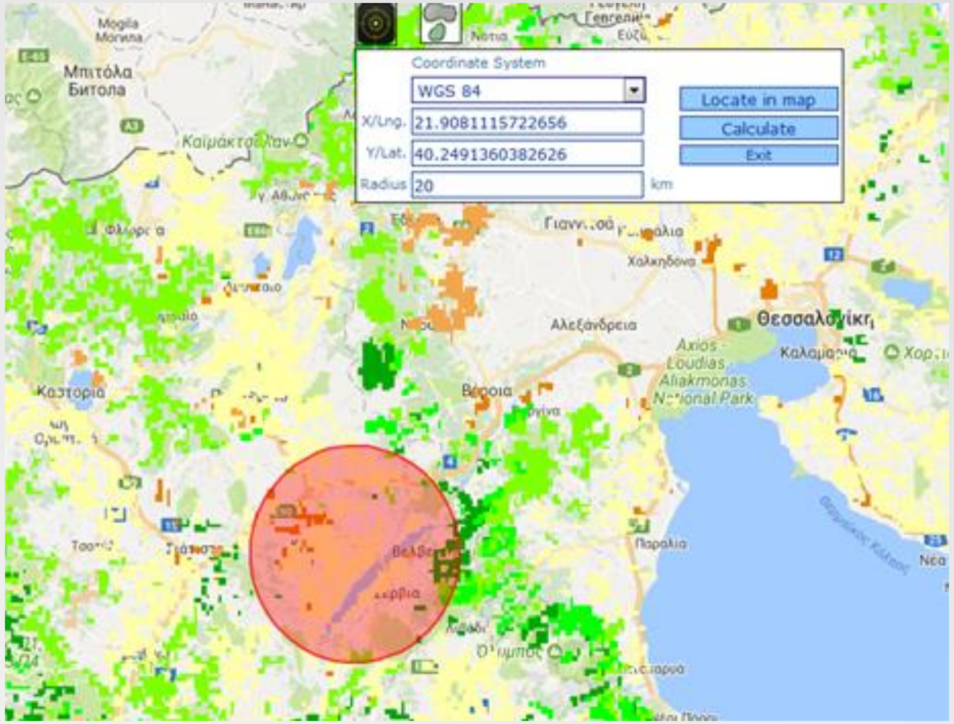
Discounted Cash Flow Calculations (yearly) [in EURO]

Operation Period	0	1	2	3	4	5	6	7	8	9	10
Operation Year	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Revenues		12,174,475	12,174,475	12,174,475	12,174,475	12,174,475	12,174,475	12,174,475	12,174,475	12,174,475	12,174,475
Biomass costs	**Baseline Scenario**	-8,882,893	-8,882,893	-7,369,994	-6,224,965	-5,869,728	-5,567,862	-4,984,942	-4,683,076	-4,381,210	-4,079,345
Total O&M		-4,235,027	-4,235,027	-4,235,027	-4,235,027	-4,235,027	-4,235,027	-4,235,027	-4,235,027	-4,235,027	-4,235,027
Gross Profit		**-943,446**	**-943,446**	**569,453**	**1,714,482**	**2,069,720**	**2,371,585**	**2,954,506**	**3,256,371**	**3,558,237**	**3,860,103**
Investment costs	-28,319,200										
Net Cash Flow	-28,319,200	-943,446	-943,446	569,453	1,714,482	2,069,720	2,371,585	2,954,506	3,256,371	3,558,237	3,860,103
Discounted Cash Flow	-28,319,200	-857,678	-779,707	427,839	1,171,015	1,285,133	1,338,698	1,516,129	1,519,121	1,509,040	1,488,237

1. Biomass Usage – Environmental Safeguards

A proposed solution containing biomass, in order to achieve high levels of efficiency and minimize all possible impacts on the environment, should follow a number of safeguards, namely :

- No transportation of biomass within large distances nor imports from neighboring countries.
- Exclude the use of arable crops.
- The quantity of the residual biomass presents an adequate capacity and should be used.
- The project relies on the maturity of the supply chain.
- Energy efficiency first principle: On the demand side there is an absolute need for extensive energy efficiency measures, in order to lower heating demand.



Example Catchment area with radius : 20 km

Source: LDK work

2. Low Enthalpy Geothermal w/ Heat Pumps

Overview & Assumptions

The assumed baseline case represents a geothermal unit of low to medium overall installed thermal capacity that can cover 10% of the total heat demand of Kozani-Ptolemaida DH systems. The plant correspond to a boiler of 15 MWth has been considered as it is expected to enhance the DH system's reliability through diversification of energy production. Such investment involves some degree of risk in terms of actual feasibility due to the technical difficulties and complexities of this technology.

*Calculations for a **15 MW_{th}** shallow geothermal plant assisted by Heat Pumps*

Shallow / low enthalpy geothermal		
Depth	30.0	m
Temperature	16.0	°C
Piping Length	6,179	km
Pipe diameter	5	cm
Water volume	600,000	m3
Geothermal Energy	4.2	GWh
Required Thermal energy from HPs	45.3	GWh
Operation period	3,500	h/y
Heat Pumps Required Capacity	15.0	MWth
Energy to DH	49.6	GWh/yr
Heat Pumps COP	3.2	-
Electrical Capacity	4.7	MW
Operation period	3,500	h/y
Thermal energy to DH	49.6	GWh/y
HPs' Electrical Consumption	16,406	MWh/y

Low Enthalpy Geothermal – CAPEX and OPEX Indicators

CAPEX	**1,242**	**€/kWth**
Heat Pumps	238	€/kWth
Horizontal Drilling/Piping	588	€/kWth
Other	417	€/kWth
OPEX	**288**	**€/kWth**
Variable	5	€/kWth
Fixed	9	€/kWth
Electricity Cost	88	€/kWth
Total	102	€/kWth

2. Low Enthalpy Geothermal w/ Heat Pumps

Key Results

- **Capacity:** 15 MWth
- **Heat production:** 49 GWh/y
- **CAPEX:** 18.6 MEUR
- **Weighted DH tariff:** 41 €/MWh
- **Simple payback:** 10.3 years
- **IRR:** 0 %
- **LCOE:** 65 EUR/MWh

Lifecycle analysis performed for 25 years

IRR is low due to proportionally higher-gradually increasing O&M costs

Green DH Solution **2**

Geothermal

Key Input data

Description	Unit	Cost/ Benefit
Income from electricity	EUR	0
Income from thermal energy	EUR	2,029,079
Total income	**EUR**	**2,029,079**
O&M costs	EUR	1,525,914
Electricity costs	EUR	-1,312,500
Fixed O&M	EUR	-140,000
Variable O&M	EUR	-73,414
Inflation	%	0%
Project Lifetime	years	25
Tax Rate	%	0
Discount Rate	%	10%
CAPEX	EUR	18,632,496

Results

Description	Unit	Value
Net Present Value (NPV)	EUR	**-13,808,301**
Pay-Back Period	years	10.3
Benefit Cost Ratio (BCR)		0.3
LCOE	€/MWh	65.1
Internal Rate of Return (IRR)	%	**0.00%**

Discounted Cash Flow Calculations (yearly) [in EURO]

Operation Period	0	1	2	3	4	5	6	7	8	9	10
Operation Year	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Revenues		2,029,079	2,029,079	2,029,079	2,029,079	2,029,079	2,029,079	2,029,079	2,029,079	2,029,079	2,029,079
Electricity costs		-1,312,500	-1,312,500	-1,312,500	-1,312,500	-1,312,500	-1,312,500	-1,312,500	-1,312,500	-1,312,500	-1,312,500
Total O&M		-164,636	-166,818	-169,516	-172,773	-174,723	-178,703	-180,673	-184,768	-186,742	-191,671
Gross Profit		**551,943**	**549,761**	**547,063**	**543,806**	**541,856**	**537,876**	**535,906**	**531,811**	**529,837**	**524,908**
Investment costs	-18,632,496										
Net Cash Flow	-18,632,496	551,943	549,761	547,063	543,806	541,856	537,876	535,906	531,811	529,837	524,908
Discounted Cash Flow	-18,632,496	501,767	454,348	411,017	371,427	336,450	303,617	275,005	248,094	224,703	202,375

2. Low Enthalpy Geothermal w/ Heat Pumps

Case studies

▪ Galanta, Slovakia

Installed geothermal capacity	7 MWth
Inhabitants connected:	1300 apartments and hospital are supplied by GeoDH
Production of heating:	25,000 MWh (90% covered by geothermal energy)
Comparison with fossil energies:	4,500 tons of CO2 saved annually when compared to use of natural gas
Installed capacity (MWth):	17.6
Operating Temperature of the DH:	• Heating loop 90/70°C – Radiator heating system in the hospital • Heating loop 77/52°C – Radiator heating in apartment houses • Heating loop 52/42°C – Radiation ceiling heating in the hospital
Others uses:	Thermal spa
Temperature of the geothermal resource (production - injection) Production:	77-78°C
DH Length (m)	2900

▪ Oradea, Romania

Installed geothermal capacity	19 MWth
Inhabitants connected:	3000 flats, 8000 people
Production of heating:	24 GWh/y
Comparison with fossil energies:	Since 2005 a geothermal heating plant has been operating in the city's Iosia district, replacing 115.000 GJ/year of lignite and natural gas, which is used at the existing CHP.
Installed capacity (MWth):	24.2 MWth
Temperature of the geothermal resource (production - injection)	104°C
Operating temperature of the DH	90°C
System Description	The geothermal heat plant was designed to supply the secondary fluid (treated water) with a temperature of 102°C (80% of heat demand for space heating at the design value of -15°C outer temperature, and 100% for DHW). The peak load for space heating is supplied by two NG fired boilers, which increase the supply temperature of the secondary fluid from 102°C to 110°C.

3. Solar Thermal w/ Heat Pumps and Seasonal Storage (PTES)

Key technical features

A solar thermal plant combined with the appropriate HPs and a large – seasonal – PTES system would mitigate intermittent solar production and provide high flexibility and reliability for the DH system.

The assumed baseline case corresponds to a plant of medium to high installed capacity that can cover 30% of the DH systems demand of Kozani and Ptolemaida. Plants of that capacity (ca. 150MW) require considerable amount of land as well as significant storage capacity.

Solar Thermal – CAPEX and OPEX Indicators

CAPEX	**464**	**€/kWth**
Solar Plant	200	*€/m2*
Storage	50	*€/m3*
Heat Pump	230	*€/kWth*
OPEX	**15.6**	**€/kWth**
Variable	0.2	*€/kWth*
Fixed	0.5	*€/kWth*
Electricity Cost	7.2	*€/kWth*
Total	7.8	*€/kWth*

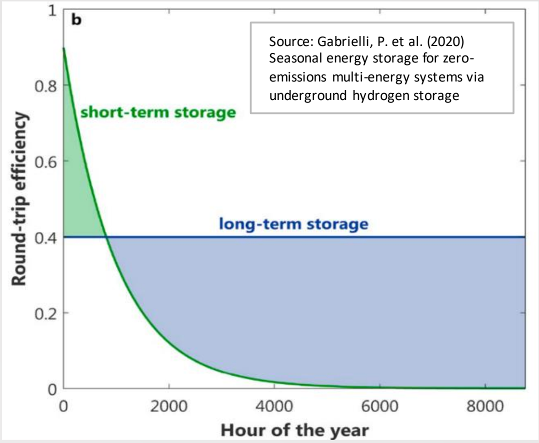
3. Solar Thermal w/ Heat Pumps and Seasonal Storage (PTES)

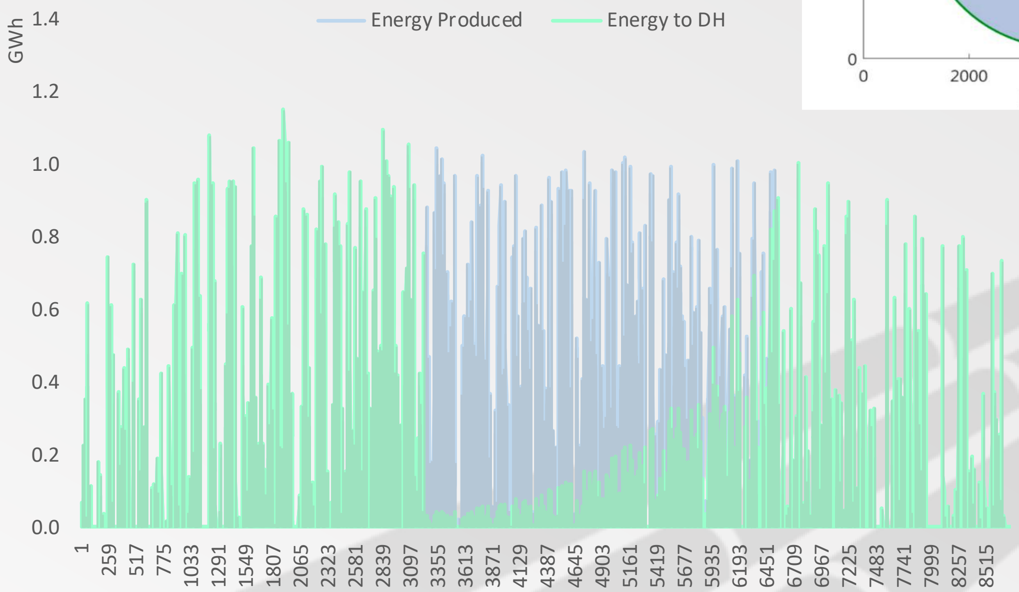
Key technical features

*Calculations for a **150 MW_{th}** Solar Thermal Plant with Heat Pumps and PTES*

Solar thermal w/ Heat Pumps & PTES		
Effective Surface	211,664	m2
Annual solar radiation	1,553	kWh/m2
Collector System Efficiency	75.0	%
Max Themal Energy Directly Produced	246.6	GWh/y
Operation period	3,500	h/y
Thermal energy to Heat Pumps	145.9	GWh/y
Directly to HP (@ 75 oC)	115.2	GWh/y
Indirectly to HP (Stored) (@ 70 oC)	30.6	GWh/y
Storage Demand	30.6	GWh/y
Average Stored Energy Content	64	kWh/m3
Required Volume Capacity	477,525	m3
Storage Factor (Indicator)	2.26	m3/m2
Average Direct Energy Content	70	kWh/m3
Direct volume	1,646	th. m3
Additional Thermal energy from HPs	40.0	GWh/y
Heat Pumps COP	3.2	-
Heat Pumps Required Capacity	12.0	MWth
Overall System Efficiency	80.0	%
Thermal energy to DH Network	148.7	GWh/y
Electricity Consumption	13,333	MWh/y

PTES provides maximum storage efficiency in the short term and enables minimum losses when shifting thermal load generated during the daytime, to the nighttime





3. Solar Thermal w/ Heat Pumps and Seasonal Storage (PTES)

Key Results

- **Capacity:** 150 MWth
- **Heat production:** 148 GWh/y
- **CAPEX:** 68.9 MEUR
- **Weighted DH tariff:** 41 €/MWh
- **Simple payback:** 11.5 years
- **IRR:** 5.1 %
- **LCOE:** 53.5 EUR/MWh

Lifecycle analysis performed for 25 years

Green DH Solution **3**

Solar Thermal

Key Input data

Description	Unit	Cost/ Benefit
Income from electricity	EUR	0
Income from thermal energy	EUR	6,087,237
Total income	**EUR**	**6,087,237**
O&M costs	EUR	1,161,033
Electricity costs	EUR	-1,066,667
Fixed O&M	EUR	-67,200
Variable O&M	EUR	-27,166
Inflation	%	0%
Project Lifetime	years	25
Tax Rate	%	0
Discount Rate	%	10%
CAPEX	EUR	68,969,049

Results

Description	Unit	Value
Net Present Value (NPV)	EUR	-24,158,614
Pay-Back Period	years	11.5
Benefit Cost Ratio (BCR)		0.6
LCOE	€/MWh	53.5
Internal Rate of Return (IRR)	%	5.08%

Discounted Cash Flow Calculations (yearly) [in EURO]

Operation Period	0	1	2	3	4	5	6	7	8	9	10
Operation Year	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Revenues		6,087,237	6,087,237	6,087,237	6,087,237	6,087,237	6,087,237	6,087,237	6,087,237	6,087,237	6,087,237
Electricity costs		-1,066,667	-1,066,667	-1,066,667	-1,066,667	-1,066,667	-1,066,667	-1,066,667	-1,066,667	-1,066,667	-1,066,667
Total O&M		-76,316	-77,124	-78,122	-79,328	-80,049	-81,522	-82,251	-83,766	-84,497	-86,321
Gross Profit		**4,944,254**	**4,943,447**	**4,942,449**	**4,941,243**	**4,940,522**	**4,939,049**	**4,938,320**	**4,936,805**	**4,936,074**	**4,934,250**
Investment costs	-68,969,049										
Net Cash Flow	-68,969,049	4,944,254	4,943,447	4,942,449	4,941,243	4,940,522	4,939,049	4,938,320	4,936,805	4,936,074	4,934,250
Discounted Cash Flow	-68,969,049	4,494,777	4,085,493	3,713,335	3,374,936	3,067,675	2,787,964	2,534,139	2,303,056	2,093,377	1,902,367

3. Solar Thermal w/ Heat Pumps and Seasonal Storage (PTES)

Case Studies

- Silkeborg, Denmark

- The worlds largest solar-thermal plant
- Supplies ~20% of Silkeborg's annual district heating demand and covers the total annual heat consumption of 4,400 households
- The solar-heating plant has a minimum lifetime of 25 years.

Construction period	2016
Capacity	110 MW
Annual production	80,000 MWh
Storage volume	4 x 16,000 m3
Solar collector area	156,694 m2
Number of solar collectors	12,436
Number of households	4,400

3. Solar Thermal w/ Heat Pumps and Seasonal Storage (PTES)

Case Studies

- Silkeborg, Denmark

- Stable price that applies to local communities which are affected less from the price fluctuations of traditional energy sources.
- The solar thermal plant benefits are estimated to 17M Euros over the next 20 years while the CAPEX was in the order of 33,5 M Euros. Benefits are derived in comparison to a business-as-usual scenario concerning the reduced operational costs, environmental costs, CO2 costs and electricity sales.
- Without government support covering 5-10% of capital costs the technology would not have been competitive.

Energy from renewables	80,000 MWh/year
Increase in energy efficiency	20% of fuel savings
CO2 reductions	15,000 tn/year
Employment	50+ employees(during construction)
Poverty and social exclusion	22,000 households with a decreased risk of poverty as the technology supports lower heating prices

3. Solar Thermal w/ Heat Pumps and Seasonal Storage (PTES)

Case Studies

- Vojens, Denmark

- The heat is absorbed to heat water, which is then transported to a 200 million liter pit, for storage.
- The total installation delivers 49 MW of peak effect, covering nearly 50% of the total heating demand.

Construction period	2012-2015
Capacity	49 MW
Annual production	28,000 MWh
Storage volume	200,000 m3
Solar collector area	70,000 m2
Number of solar collectors	5,439
Number of households	2,000

3. Solar Thermal w/ Heat Pumps and Seasonal Storage (PTES)

Case Studies

- Vojens, Denmark

- The 13 meter deep storage pit has a circumference of 610 meters. It takes about five months to fill the pit to its maximum of 200 million liters with a pumping capacity of 50,000 liters of water per hour.
- The double-sealed bottom plastic liner is supplemented by a floating top liner covered by a 60-cm layer of insulating expanded clay, which again is covered by a top-liner.
- The large-scale investment of around € 9M will provide with savings of 10-15% on the annual heating bill, and the plant saves from 6,000 tones of CO_2 per year.

Temperature range (^0C)	40-90
Heat storage Capacity(MWh)	12,180
(Dis)charge capacity (kW)	38,500
Total estimated heat losses(MWh/year)	5,500
Heat lost each year related to discharges	14%

4. Biogas CHP

Overview & Assumptions

The biogas market is relatively limited, and its supply chain is characterized by high competition among the small biogas CHP plants operating in the region. A biogas plant for DH production could only be included to diversify options of thermal energy production, however, with a low installed capacity due to very limited raw material potential.

Calculations for a 5.5 MW_{th} Biogas CHP Plant

Biogas CHP		
Electrical capacity	5.16	MW
Electrical capacity (own)	0.52	MW
Electrical efficiency	42.0	%
Heat efficiency	45.0	%
Heat Capacity	5.53	MWth
Fuel input	12.30	MW
Operation	8,500	h/y
Thermal energy UF	80%	%
Power generation	43,894	MWh/y
Biogas	107,706,286	kWh/y
Generated heat	37,623	MWh/y
Demand Coverage	8%	%

Πίνακας 29: Διαθέσιμο δυναμικό βιομάζας Δυτικής Μακεδονίας

Περιφερειακή Ενότητα	Διαθέσιμο Δυναμικό αγροτικής βιομάζας (GJ/ έτος)	Διαθέσιμο Δυναμικό δασικής βιομάζας (GJ/ έτος)	Διαθέσιμο CH_4 (m^3/έτος)
Γρεβενών	211,900.91	42,347.93	2,059,831
Καστοριάς	354,476.04	67,636.99	1,346,345
Κοζάνης	1,791,267	29,593.66	6,000,504
Φλώρινας	845,948	52,243.65	4,716,066
Σύνολο	**3,203,591.95**	**162,228.57**	**14,122,746**

Source: ΕΚΕΤΑ/ΙΔΕΠ

Biogas CHP – CAPEX and OPEX Indicators

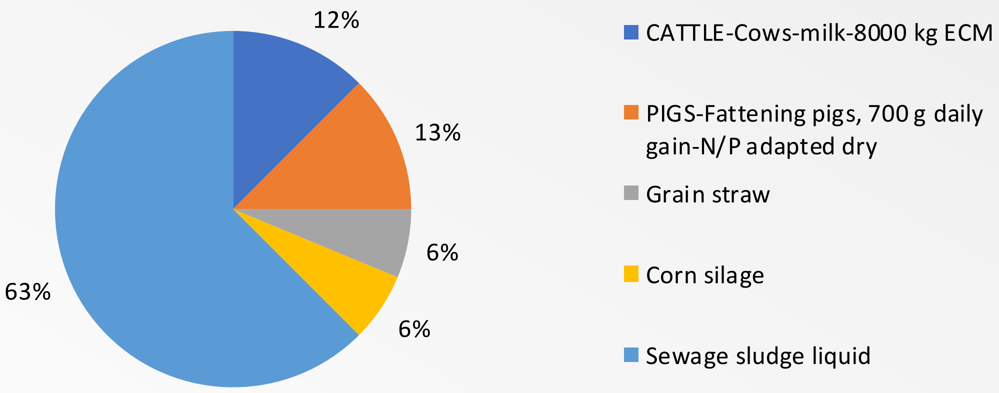
CAPEX	**2,867**	**€/kWth**
OPEX	**1,303**	**€/kWth**
Variable	1,291	*€/kWth*
Fixed	12	*€/kWth*

4. Biogas CHP

Key results

- A specialized model for pre-feasibility analysis of biogas plants was utilized
- A mix of animal manure, corn and grain silage and sewage sludge for dilution assumed

Feedstock quantities



2. INPUTS-FEEDSTOCK			
2.1	CATTLE-Cows-milk-8000 kg ECM	ton/y	73,000
2.2	PIGS-Fattening pigs, 700 g daily gain-N/P adapted dry	ton/y	73,000
2.3	Grain straw	ton/y	36,500
2.4	Corn silage	ton/y	36,500
2.5	Sewage sludge liquid	ton/y	365,000
3. BIOGAS Plant			
3.1	Digesters:Vertical	m3	56,000
3.2	CHP with capacity	kWe	5,416
4. OUTPUTS			
3.1	Electricity to grid	MWh/y	46,039
3.2	Thermal energy produced	MWh/y	49,328
3.3	Thermal energy utilised	MWh/y	36,472
3.4	Total Digestate	ton/y	569,762
3.5	Solid digestate	ton/y	
3.6	Liquid digestate sold	ton/y	284,881
3.9	Nitrogen fertilizer - equivalent weight	ton/y	1321.3
3.10	P2O5-fertilizer - equivalent weight	ton/y	963.6
3.11	K2O-fertilizer - equivalent weight	ton/y	1124.2
4.11	Biomethane	Nm3/y	
5. CAPEX			
4.1	Biogas plant	Euro	14,032,862
4.2	Digestate treatment-storage	Euro	11,520,000
4.3	Biogas upgrading	Euro	
4.4	**Total Investment costs**	**Euro**	**25,552,862**
6. REVENUES and OPEX			
5.1	Revenues from electricity sales	Euro/y	7,044,007
5.2	Revenues from thermal energy savings	Euro/y	1,094,164
5.3	Revenues from liquid digestate sales-NO separation	Euro/y	569,762
5.8	**Total revenues**	**Euro/y**	**8,707,933**
5.9	Cost for utilities	Euro/y	359,106
5.10	Maintenance costs	Euro/y	549,740
5.11	Other costs	Euro/y	5,900,000
5.12	**Total operating costs**	Euro/y	**6,808,847**
5.13	Net profit	**Euro/y**	1,899,086
7. FINANCIAL RESULTS			
6.1	*Simple payback period*	*years*	*13.5*
6.2	*IRR*	*%*	*0.4%*
6.3	*NPV*	*Euro*	*-13,108,540*

4. Biogas CHP

Case Studies

- Lemvig, Denmark

- The plant treats organic residual products and slurry from approximately 75 farms.
- It generates around 5.3-5.7 million Nm3 /year of biomethane, and 8.1-8.8 million Nm3 /year of biogas.

Operational since	1991, major renovation 2008
Input substrate (2011)	Around 615 ton/day (83% manure and 17% organic waste)
Gas production capacity	18,5 GWh/year
Heat utilization	Heating of 1,400 houses at the Lemvig Municipality

4. Biogas CHP

Case Studies

- Lemvig, Denmark
  - The plant operates in thermophilic conditions and has 4 digesters, 3 older ones with a capacity of 2,400 m3 each and a new digester of 7,100 m
  - Lemvig biogas plant was estabilised by a consortium of 79 farmers and currently is owned by 69 local farmers in a 100% privately owned cooperative.
  - The cost of the locally produced heat from biogas was around 45% lower than the heat produced from natural gas.

Process	4 digesters with a total capacity of 14,300 m3
Biogas pipeline	4.3 km from the biogas plant to the Lemvig district heating plant
Installed power at the Lemvig district heating plant	2 Mwel 2.2 MWth
Investment	Project cost in 1992: 7 million EUR (1.8 million EUR subsidies from state). New reactor cost in 2008: 1.6 million EUR. Cost of the plant gas engine in 2005: 1.6 million EUR

4. Biogas CHP

Case Studies

- Steinfurt, Germany

- The biogas plant was initially connected with two CHP plant of 347kWel and 536 kWel capacity. The heat is fed into the district heating system.
- About 4 GWh of heat are generated by the CHP unit.

Commissioning date	2005
Input substrate	Per day: 30 tons of maize/day grown on abandoned areas, 10-30 tons of manure and 10 tons of agricultural by-products.
CO2 savings	5,000 tons
Heat utilization	20,000 m2 public building, school center, health center, outdoor pool and retirement home

4. Biogas CHP

Case Studies

- Steinfurt, Germany
  - In 2009 a third satellite CHP was commissioned.
  - In 2010, a fourth satellite CHP started its operation.
  - 46 farmers and 23 investors established the company named Bioenergy Steinfurt GmbH & Co.
  - The project received a state grant from Nordrhein-Westfalen and a loan from KfW Bank.
  - The biogas plant can cover up to 80% of the heat demand of the local administration Building.

Installed power	1. CHP: 347 kWel and 390 kWth 2. CHP: 536 kWel and 505 kWth 3. CHP: 380 kWel and 390 kWth 4. CHP: 380 kWel and 390 kWth
Investment costs	3.5 million EUR
Support	Loan from KfW Bank (90,000 EUR), state grant
Annual savings	35,000 EUR heat cost for natural gas

DH systems modeling tools used

Inhouse: Biogas plant optimization tool

European Bank for Reconstruction and Development — QUICK SCAN MODEL — Created by: LDK

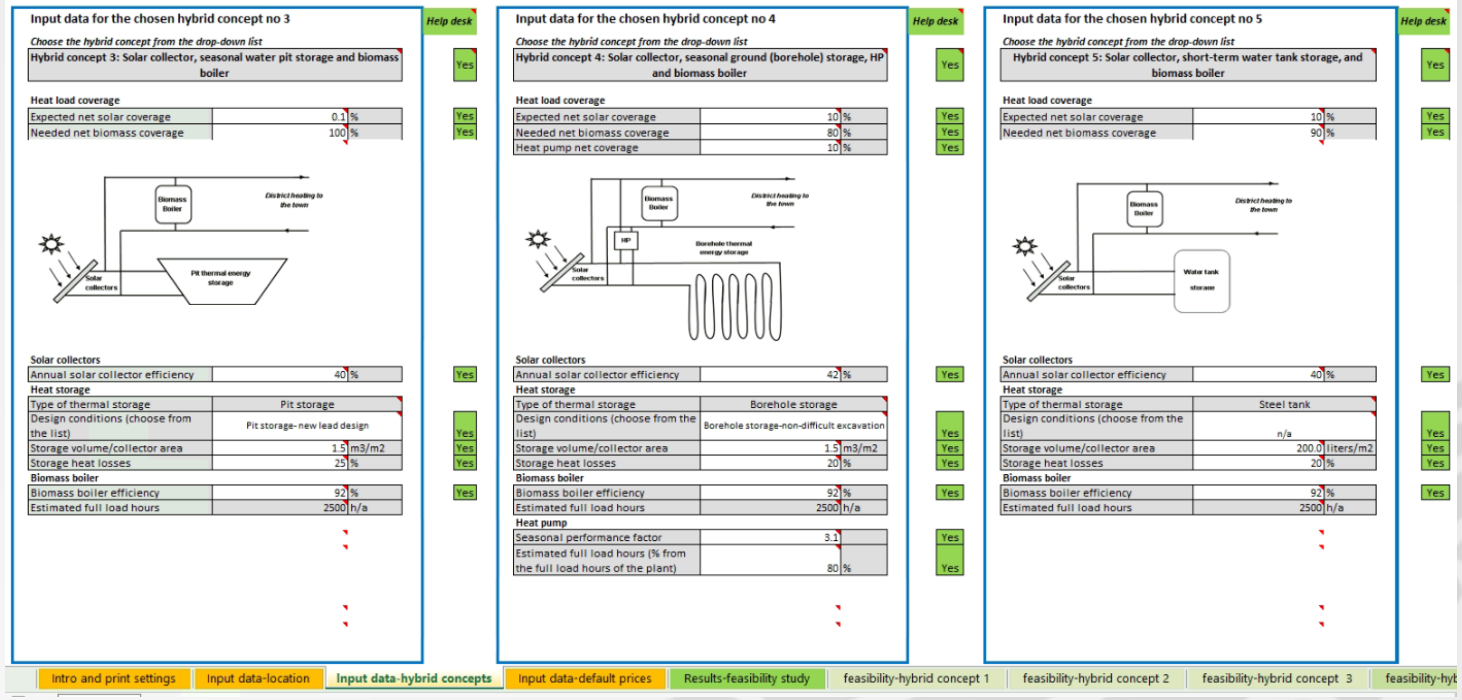
FOR PRELIMINARY ANALYSIS OF FINANCIAL VIABILITY OF BIOGAS INSTALLATIONS

Project Name: W. Macedonia
Country: Greece

2 Assumptions-Inputs

SN	Description	Unit	Value	Attention
1. Key Technical parameters				
1.1	Operation	h/y	8,500	
1.2	LHV Methane	kWh/Nm^3	9.97	
1.3	Methane density	kg/m^3	0.72	
1.4	CO_2 specific weight	kg/m^3	1.87	
1.5	EF3	kg N_2O/kg N excreted	0.02	
1.6	Manure left in open space	%	100%	
1.7	Biogas emitted from lagoons	% total biogas	70%	
1.8	Emission factor-electricity	tCO_2/MWhe	0.989	
1.9	Emission factor-gas	tCO_2/MWh fuel	0.202	
2. Technical-operational of plant				
Digester-CHP				
2.0	Is electricity produced from the biogas plant		YES	
2.1	CHP electrical efficiency	%	42%	
2.2	CHP thermal efficiency	%	45%	
2.3	Heating up input of digesters	$kWhth/m^3sub$	5.00	
2.4	Radiation losses in digesters	$kWhth/m^3sub$	1.40	
2.5	Hydraulic retention time	days	35	
2.6	Amount of CHP heat utilised	%	80	
2.6b	Amount of heat utilised (heat only mode)	%	50	
2.7	Displaced fuel for thermal energy		Natural gas	
Digestate separation-liquid				
2.8	Is there digestate separation to liquid-solid part		NO	
2.9	In case of NO digestate separation-% of liquid sold as fertiliser	%	50%	
2.10	Digestate separation: % of digestate to liquid	%	.	
2.11	Digestate separation - is liquid digestate sold?		YES	
2.12	If yes what percentage	%	80	
Digestate separation-2nd stage (pure water)				
2.13	Is there further purification of liquid digestate?		NO	
2.14	Is pure water from further separation used/replaces water?		NO	
2.15	If yes what percentage of initial liquid digestate is processed?	%	0%	
2.16	2nd stage liquid separation- % to pure water	%	60%	
Digestate separation-solids				
2.17	Nitrogen Sales/utilisation-solid fertiliser		YES	
2.18	What percentage	%	60	
2.19	P_2O_5-Sales/utilisation-solid fertiliser		YES	
2.20	What percentage	%	100	
2.21	K_2O Sales/utilisation- solid fertiliser		YES	
2.22	What percentage	%	98	
2.23	% of manure subject to gate fees	%	0	

Sunstore 4 feasibility evaluation tool



4. Sustainable Roadmap for Western Macedonia

Approach

For the determination of the sustainable scenario-roadmap for W. Macedonia DH systems the following approach has been followed:

Step	Description	Comment
1	Drafting of general techno-economic and socio-economic assumptions	To be elaborated in the multicriteria analysis
2	Requirements- boundaries	Baseline case- Options and max parameters
3	Scenarios development	Modelling and extraction of key financial indicators for various mixes of the selected technologies
4	Multicriteria analysis	Comparative ranking of sub cases based on multicriteria analysis
5	Selection of optimal scenario	Final selection based on environmental criteria
6	Implementation Roadmap	Specific timing and sequence for gradual deployment of green DH solutions

Step 1. General Assumptions

Techno-Economic

General Assumptions	Value	Unit
Tariffs		
Electricity purchase	95.0	€/MWh
DH (Weighted)	40.9	€/MWhth
Economy		
Inflation	0.0%	%
Tax Rate	0.0%	%
Discount Rate	10.0%	%
Projects - General		
Project Lifetime	25	years
Operation period	3,500	h/y

The socio-economic aspects of the investment mainly refer to:

1. Income generation
2. Employment creation
3. Addressing of energy poverty in the area

In the area and in time framework of 2021-2023:
~ 1.850 jobs are at stake (direct impact)
~ 5.320 jobs are at stake in all sectors as an indirect impact
91.450.000€ is deprived as income from the local economy

2021-2023

Transition Phase

-3,35GW *(Ptoleaida V not included)*

The period is key to ensuring jobs and income in the local economy

The construction phase of both scenarios can contribute to the above

Socio-Economic

	Construction Period	Construction/Instalaltion	Manufacturing	O&M	Energy Demand		Source
	Years	Jobs years/MW		Jobs/MW	Jobs/PJ	Jobs/GWh	
Gas	2	1.3	0.93	0.14	Regional		1
Biomass	2	14	2.9	1.5	29.9	0.107639914	1
Geothermal	2	6.8	3.9	0.4	-		1
Solar Thermal	2	8	4	0.6	-		1
Geothermal- Heat	6.9 jobs/ MW (construction and manufacturing)						1
Solar-Heat	8.4 jobs/ MW (construction and manufacturing)						1
CHP	CHP technologies use the factor for the technology, i.e. coal, gas, biomass, geothermal etc, increased by a factor of 1.5 for O&M only.						1
Biogas PP	-	14	2.9	2.25	29.9		2

Sources:

1. Rutovitz, J Dominish, E Downes, J., 2015 - Calculating global energy sector jobs: 2015 methodology. Institute for Sustainable Futures, UTS, pp. 1-48
2. Ram, M.; Aghahosseini, A.; Breyer, C.; 2019. Job creation during the global energy transition towards 100% renewable power system by 2050. Technological Forecasting and Social Change. DOI: 10.1016/j.techfore.2019.06.008

Step 2. Requirements-boundaries

Baseline Scenario of "Just Transition Development Plan of Lignite Areas"

DH Plant	Installed Capacity [MW]	Thermal Energy Production [GWh]
Ptolemaida V	140	300 - 400
Electric boiler	80	10 - 125
High Efficiency CHP	60	270 - 350
Gas boiler	100	10 - 125
Total	380	600 - 1,000

Ptolemaida V CHP plant's contribution as a **base load** unit for district heating, has been considered in any sustainable scenario proposed until 2028

Electric Boiler plant's contribution as a **peak load** unit for district heating, has been considered as back-up in any sustainable scenario proposed until 2028

Both High Efficiency CHP & Gas Boiler plants are redundant according to the sustainable scenario proposed until 2028

The Green District Heating Hub's technical requirements, considering at least the contribution of Ptolemaida V CHP plant will incorporate the following overall capacity:

Overall Thermal Capacity: *> 250 MW_{th}*

Thermal Energy Production: *> 500 GWh_{th}/yr*

Green DH Hub's targets for 2028

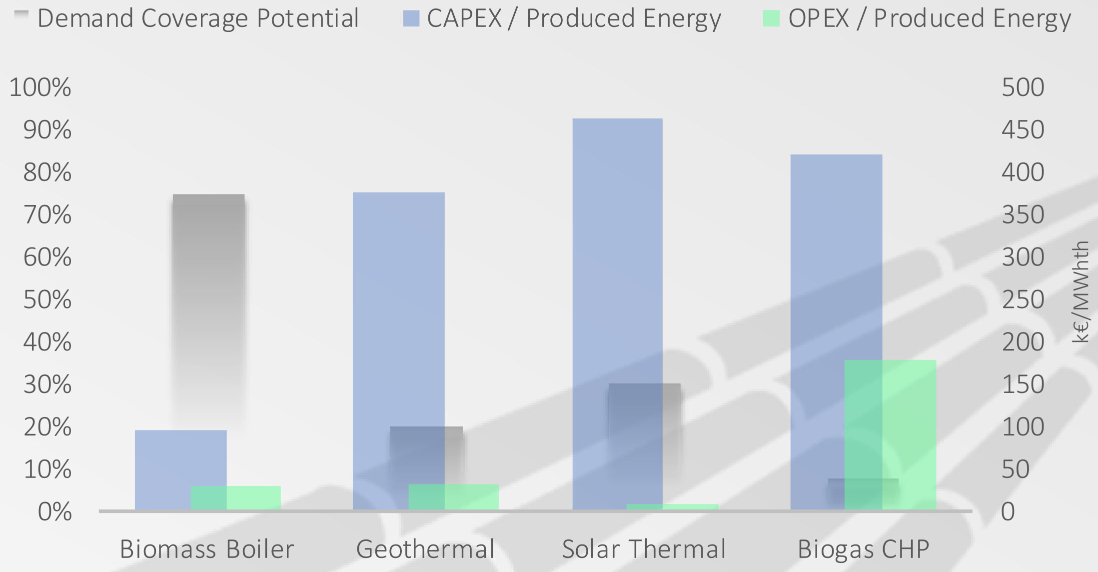
Step 2. Requirements-boundaries

Constraints, Limitations and Potential

Technology	Constraints	Limitations	Max Estimated Potential		% of Demand (500 GWh/yr)
			Installed Capacity [MW]	Thermal Energy [GWh]	
Biomass Boiler	Immature supply chain	Feedstock < 100,000 tn/yr	120	370	75%
Low Enthalpy Geothermal w/ HPs	Technical difficulties and complexities	Installed capacity < 30 MW	30	100	20%
Solar Thermal w/ HPs & PTES	Surface required	Surface < 250,000 m^2	150	150	30%
Biogas CHP	Limited supply chain	Available CH_4 < 10,000,000 m^3/year	6	37	8%
Total			306	657	133%

Notes

- For the biomass feedstock the max quantity corresponds to about 50% of sustainable potential identified, which is about 6 time more than biomass stock for Amynteo plant, and requires a significant level of supply chain organization and planning
- The relevant biomass utilization scenarios do not take into account the potential development of the biomass CHP plant from PPCR (demanding a substantial share of available biomass in the region)
- For solar the upper limit exceeds the max recorded solar DH plant up to date



Step 3. Scenarios development

Key outputs per option "sub-case"

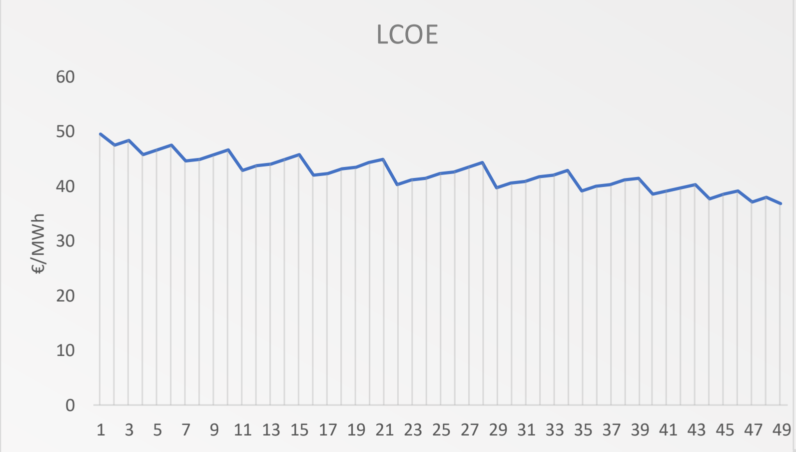
																Jobs		
Biomass	Geothermal	Solar Therma	Biogass	Income	Electricity Cost	Ficed Cost	Variable Cost	Ramp rate	CAPEX	LCOE	NPV	SPB	IRR	BCR	Application R	Construction	Operation	Total
40%	30%	30%	0%	20,290,791	5,972,708	4,653,110	644,378	6.0	144,988,171.8	49.5	-60,852,570	16.1	3.93%	0.58	25%	3,336	222	3,558
45%	25%	30%	0%	20,290,791	5,382,839	5,088,289	656,979	5.5	137,410,773.8	47.7	-51,941,316	15.0	4.60%	0.62	26%	3,386	234	3,620
45%	30%	25%	0%	20,290,791	5,905,061	5,151,756	689,409	6.0	135,853,263.7	48.5	-55,880,989	15.9	4.06%	0.59	27%	3,171	222	3,393
50%	20%	30%	0%	20,290,791	4,792,969	5,543,619	669,581	6.5	129,833,375.7	46.0	-43,212,978	14.0	5.31%	0.67	26%	3,438	246	3,684
50%	25%	25%	0%	20,290,791	5,315,191	5,607,086	702,010	6.5	128,275,865.6	46.7	-47,152,650	14.8	4.76%	0.63	28%	3,222	234	3,456
50%	30%	20%	0%	20,290,791	5,837,413	5,670,553	734,440	7.0	126,718,355.6	47.5	-51,092,323	15.7	4.18%	0.60	29%	3,006	222	3,228
55%	15%	30%	0%	20,290,791	4,290,599	6,047,039	682,682	6.0	123,498,144.0	44.7	-36,960,345	13.3	5.82%	0.70	27%	3,489	257	3,746
55%	20%	25%	0%	20,290,791	4,725,321	6,101,172	714,612	6.5	120,698,467.5	45.1	-38,776,102	13.8	5.48%	0.68	28%	3,274	245	3,519
55%	25%	20%	0%	20,290,791	5,247,544	6,164,639	747,041	6.5	119,140,957.5	45.9	-42,715,775	14.7	4.90%	0.64	30%	3,057	233	3,290
55%	30%	15%	0%	20,290,791	5,769,766	6,228,106	779,470	7.0	117,583,447.4	46.6	-46,655,447	15.6	4.28%	0.60	31%	2,842	222	3,064
60%	10%	30%	0%	20,290,791	3,700,729	6,602,462	695,284	6.0	115,920,746.0	43.1	-29,140,549	12.5	6.53%	0.75	27%	3,542	269	3,811
60%	15%	25%	0%	20,290,791	4,222,952	6,665,928	727,713	6.0	114,363,235.9	43.9	-33,080,221	13.2	5.96%	0.71	29%	3,326	257	3,583
60%	20%	20%	0%	20,290,791	4,657,674	6,720,062	759,643	6.5	111,563,559.4	44.3	-34,895,978	13.7	5.60%	0.69	30%	3,110	245	3,355
60%	25%	15%	0%	20,290,791	5,179,896	6,783,528	792,072	6.5	110,006,049.4	45.1	-38,835,651	14.6	4.97%	0.65	32%	2,894	234	3,128
60%	30%	10%	0%	20,290,791	5,702,118	6,846,995	824,501	7.0	108,448,539.3	45.9	-42,775,323	15.7	4.30%	0.61	33%	2,679	222	2,901
65%	5%	30%	0%	20,290,791	3,198,360	7,196,200	708,385	5.0	109,585,514.3	42.0	-23,707,741	11.9	7.03%	0.78	28%	3,594	280	3,874
65%	10%	25%	0%	20,290,791	3,633,082	7,250,333	740,315	6.0	106,785,837.8	42.4	-25,523,499	12.3	6.70%	0.76	29%	3,378	268	3,646
65%	15%	20%	0%	20,290,791	4,155,304	7,313,800	772,744	6.0	105,228,327.8	43.2	-29,463,171	13.1	6.09%	0.72	31%	3,161	256	3,417
65%	20%	15%	0%	20,290,791	4,590,026	7,367,933	804,673	6.5	102,428,651.3	43.5	-31,278,929	13.6	5.71%	0.69	32%	2,946	245	3,191
65%	25%	10%	0%	20,290,791	5,112,248	7,431,400	837,103	6.5	100,871,141.2	44.3	-35,218,601	14.6	5.02%	0.65	34%	2,730	233	2,963
65%	30%	5%	0%	20,290,791	5,634,471	7,494,867	869,532	6.5	99,313,631.2	45.1	-39,158,274	15.8	4.29%	0.61	35%	2,515	221	2,736
70%	0%	30%	0%	20,290,791	2,608,490	7,794,558	720,987	3.0	102,008,116.2	40.5	-16,277,667	11.1	7.84%	0.84	28%	3,644	291	3,935
70%	5%	25%	0%	20,290,791	3,130,712	7,858,024	753,416	5.0	100,450,606.2	41.3	-20,217,339	11.8	7.25%	0.80	30%	3,429	279	3,708
70%	10%	20%	0%	20,290,791	3,565,434	7,912,158	785,346	6.0	97,650,929.7	41.7	-22,033,097	12.2	6.89%	0.77	31%	3,212	267	3,479
70%	15%	15%	0%	20,290,791	4,087,656	7,975,624	817,775	6.0	96,093,419.6	42.5	-25,972,769	13.0	6.23%	0.73	33%	2,996	256	3,252
70%	20%	10%	0%	20,290,791	4,522,379	8,029,758	849,704	6.5	93,293,743.2	42.8	-27,788,527	13.5	5.81%	0.70	34%	2,781	244	3,025
70%	25%	5%	0%	20,290,791	5,044,601	8,093,224	882,134	6.0	91,736,233.1	43.6	-31,728,199	14.6	5.06%	0.65	36%	2,565	232	2,797
70%	30%	0%	0%	20,290,791	5,566,823	8,156,691	914,563	6.0	90,178,723.0	44.4	-35,667,872	16.0	4.26%	0.60	37%	2,350	220	2,570
75%	0%	25%	0%	20,290,791	2,540,842	8,471,121	766,018	3.0	92,873,208.1	39.8	-12,921,052	10.9	8.12%	0.86	30%	3,480	291	3,771
75%	5%	20%	0%	20,290,791	3,063,064	8,534,588	798,447	5.0	91,315,698.0	40.6	-16,860,725	11.6	7.48%	0.82	32%	3,264	279	3,543
75%	10%	15%	0%	20,290,791	3,497,787	8,588,721	830,376	6.0	88,516,021.6	41.0	-18,676,482	12.0	7.10%	0.79	33%	3,048	268	3,316
75%	15%	10%	0%	20,290,791	4,020,009	8,652,188	862,806	6.0	86,958,511.5	41.8	-22,616,155	12.9	6.37%	0.74	35%	2,832	256	3,088
75%	20%	5%	0%	20,290,791	4,454,731	8,706,321	894,735	6.0	84,158,835.0	42.2	-24,431,912	13.5	5.91%	0.71	36%	2,617	244	2,861
75%	25%	0%	0%	20,290,791	4,976,953	8,769,788	927,165	5.5	82,601,325.0	43.0	-28,371,585	14.7	5.08%	0.66	38%	2,401	232	2,633
80%	0%	20%	0%	20,290,791	2,473,195	9,157,342	811,049	3.0	83,738,300.0	39.2	-9,652,101	10.7	8.45%	0.88	32%	3,315	291	3,606
80%	5%	15%	0%	20,290,791	2,995,417	9,220,809	843,478	5.0	82,180,789.9	40.0	-13,591,774	11.4	7.74%	0.83	34%	3,100	280	3,380
80%	10%	10%	0%	20,290,791	3,430,139	9,274,942	875,407	6.0	79,381,113.4	40.3	-15,407,531	11.8	7.33%	0.81	35%	2,884	268	3,152
80%	15%	5%	0%	20,290,791	3,952,361	9,338,409	907,837	5.5	77,823,603.4	41.1	-19,347,204	12.8	6.53%	0.75	37%	2,668	256	2,924
80%	20%	0%	0%	20,290,791	4,387,084	9,392,542	939,766	5.5	75,023,926.9	41.5	-21,162,961	13.5	6.02%	0.72	38%	2,453	244	2,697
85%	0%	15%	0%	20,290,791	2,405,547	9,844,958	856,079	3.0	74,603,391.8	38.5	-6,395,809	10.4	8.85%	0.91	34%	3,151	291	3,442
85%	5%	10%	0%	20,290,791	2,927,769	9,908,424	888,509	5.0	73,045,881.8	39.3	-10,335,481	11.1	8.07%	0.86	36%	2,936	279	3,215
85%	10%	5%	0%	20,290,791	3,362,492	9,962,558	920,438	5.5	70,246,205.3	39.7	-12,151,239	11.6	7.62%	0.83	37%	2,720	267	2,987
85%	15%	0%	0%	20,290,791	3,884,714	10,026,024	952,868	5.0	68,688,695.2	40.5	-16,090,911	12.7	6.73%	0.77	39%	2,504	255	2,759
90%	0%	10%	0%	20,290,791	2,337,900	10,575,325	901,110	3.0	65,468,483.7	37.9	-3,527,575	10.1	9.28%	0.95	36%	2,987	290	3,277
90%	5%	5%	0%	20,290,791	2,860,122	10,638,792	933,540	4.5	63,910,973.6	38.7	-7,467,248	10.9	8.41%	0.88	38%	2,772	278	3,050
90%	10%	0%	0%	20,290,791	3,294,844	10,692,925	965,469	5.0	61,111,297.2	39.1	-9,283,005	11.4	7.91%	0.85	39%	2,556	266	2,822
95%	0%	5%	0%	20,290,791	2,270,252	11,307,103	946,141	2.5	56,333,575.6	37.4	-672,145	9.8	9.84%	0.99	38%	2,822	290	3,112
95%	5%	0%	0%	20,290,791	2,792,474	11,370,570	978,571	4.0	54,776,065.5	38.2	-4,611,818	10.6	8.86%	0.92	40%	2,607	278	2,885
100%	0%	0%	0%	20,290,791	2,202,604	12,038,881	991,172	2.0	47,198,667.4	36.8	2,183,285	9.3	10.62%	1.05	40%	2,659	289	2,948

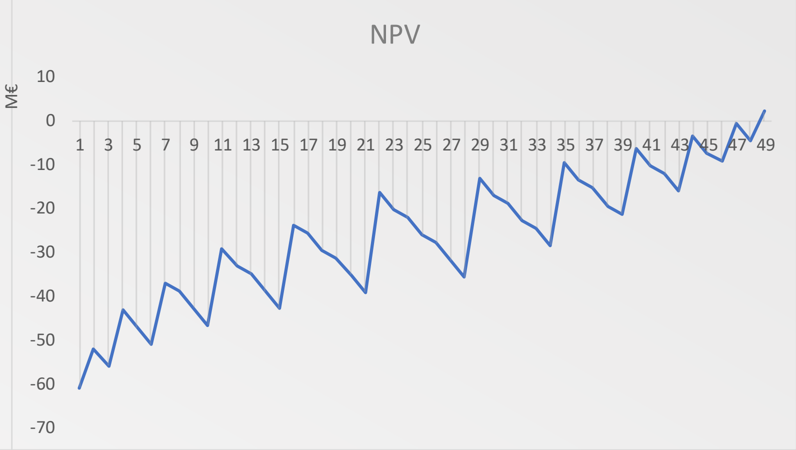
Notes

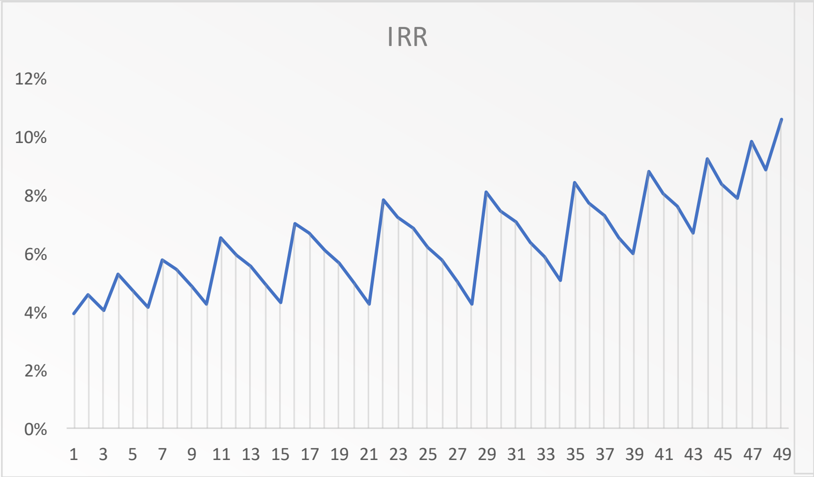
- Biogas option not taken into account due to small share of heat coverage, and risk of resource supply
- 50 sub cases elaborated with different mixes of biomass, geothermal and solar share, with boundaries being :
  - Biomass: 40-100%
  - Geothermal: 0-30%
  - Solar: 0-30%

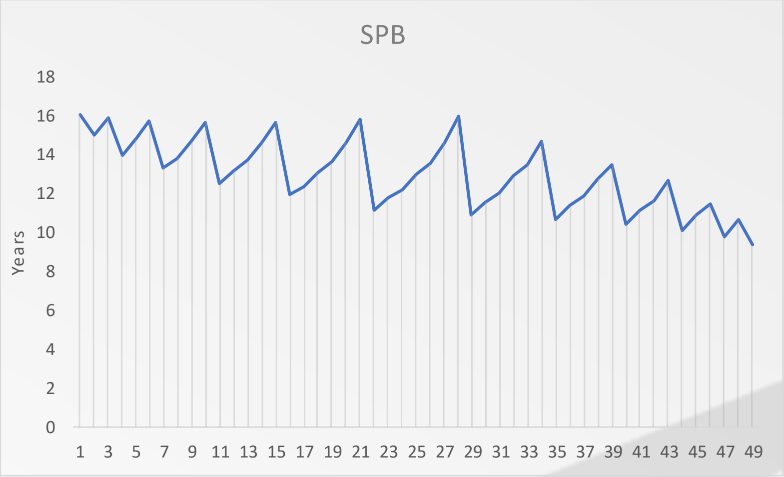
Step 3. Scenarios development

Results









SN	Biomass	Geothermal	Solar Thermal
1	30%	30%	40%
2	35%	25%	40%
3	35%	30%	35%
4	40%	20%	40%
5	40%	25%	35%
6	40%	30%	30%
7	45%	15%	40%
8	45%	20%	35%
9	45%	25%	30%
10	45%	30%	25%
11	50%	10%	40%
12	50%	15%	35%
13	50%	20%	30%
14	50%	25%	25%
15	50%	30%	20%
16	55%	5%	40%
17	55%	10%	35%
18	55%	15%	30%
19	55%	20%	25%
20	55%	25%	20%
21	55%	30%	15%
22	60%	0%	40%
23	60%	5%	35%
24	60%	10%	30%
25	60%	15%	25%
26	60%	20%	20%
27	60%	25%	15%
28	60%	30%	10%
29	65%	0%	35%
30	65%	5%	30%
31	65%	10%	25%
32	65%	15%	20%
33	65%	20%	15%
34	65%	25%	10%
35	65%	30%	5%
36	70%	0%	30%
37	70%	5%	25%
38	70%	10%	20%
39	70%	15%	15%
40	70%	20%	10%
41	70%	25%	5%
42	70%	30%	0%
43	75%	0%	25%
44	75%	5%	20%
45	75%	10%	15%
46	75%	15%	10%
47	75%	20%	5%
48	75%	25%	0%
49	80%	0%	20%
50	80%	5%	15%
51	80%	10%	10%
52	80%	15%	5%
53	80%	20%	0%
54	85%	0%	15%
55	85%	5%	10%
56	85%	10%	5%
57	85%	15%	0%
58	90%	0%	10%
59	90%	5%	5%
60	90%	10%	0%
61	95%	0%	5%
62	95%	5%	0%
63	100%	0%	0%

Notes

- Financial viability gradually improves with increasing share of biomass boiler size
- Intermediate escalations are due to increasing share of geothermal which reduced financial viability compared with solar.

Step 4. Multicriteria Analysis

1. Evaluation Criteria & Weighting factors

For the purpose of the final evaluation of the generated sustainable scenarios, the most important parameters considered are:

- **Levelized Cost of Energy (LCOE)**: Crucial parameter for evaluating the sustainable scenarios in terms of their final pricing levels
- **Internal Rate of Return (IRR):** Metric used to evaluate the profitability of each sustainable scenario
- **Ramp Rate:** Technical feature characterizing the flexibility of each proposed sustainable scenario in terms of its demand response capabilities
- **Application Risk:** Parameter enabling to mitigate inherent risks of Biomass and Geothermal technologies. Raising DH system's dependence in biomass, increases the levels of risk, due to the immature supply chain of agricultural residues as well as their unregulated prices. The risks of low enthalpy geothermal, lie in the difficulties and complexities in terms of technical feasibility.
- **Jobs generated:** Crucial parameter of socio-economic nature. Each scenario has been further evaluated based on the jobs it generates and most importantly in the long-term (during the operation stage)

Based on the last two parameters **two main scenarios** were targeted and assessed. **One for maximization of jobs** generated (Scenario 1) and a second of **mitigating the application risks** (Scenario 2). The following table illustrates the weighting factors attributed on the parameters of each scenario:

		LCOE	IRR	Ramp Rate	Application Risk	Jobs		Total
						Construction	Operation	
Scenario 1	Max Jobs	30%	10%	10%	10%	10%	30%	**100%**
Scenario 2	Application Risk	30%	10%	10%	30%	10%	10%	**100%**

Levelized Cost of Energy (LCOE): a measure of the average net present cost of energy generation for a generating plant over its lifetime. It represents the average revenue per unit of energy generated that would be required to recover the costs of building and operating a generating plant during an assumed financial life and duty cycle.

Ramp Rate: a measure to quantify a power plant's flexibility. Represents the demand response capacity of each technology. Biomass is characterized by the lowest flexibility compared to the other solutions proposed, due to the requirement of constantly supplying variable feedstock quantities to meet fluctuating demand, as well as the boiler's conventional technology. The other two technologies are both assisted by heat pumps which consume electricity thus having significant comparative advantage in terms of demand response capacity. Moreover, especially for solar thermal plant the contribution of the PTES, further increases its response capability.

Step 4. Multicriteria Analysis

2. Potential Scenarios

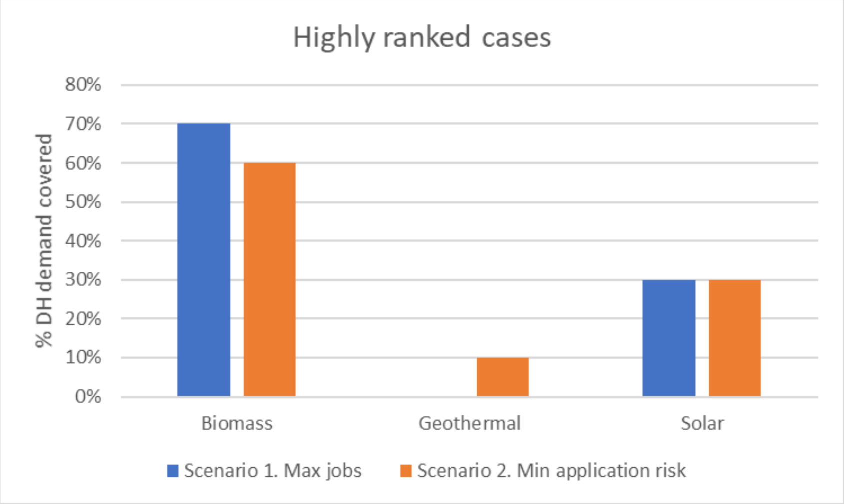
The weighting factors were applied to rank each sub case for each sustainable scenario and the most high ranked sub cases in each scenario are the following:

			Capacity [MW]			
			Biomass	Geothermal	Solar Thermal	Total
Scenario 1	Max Jobs	Biomass [70%] & Geothermal [0%] & Solar Thermal [30%]	110	0	150	**260**
Scenario 2	Min Application Risk	Biomass [60%] & Geothermal [10%] & Solar Thermal [30%]	94	15	150	**260**

2.1 Jobs Created per Sustainable Scenario (Socio-Economic Considerations)

Based on the job generation indicators (Socio-economic assumptions) and corresponding capacities of each green solution resulted under potential scenarios, the total number of jobs to be created as per sustainable scenario, was calculated:

	Construction		Operation		Total	
	Scenario 1	Scenario 2	Scenario 1	Scenario 2	Scenario 1	Scenario 2
Biomass Boiler	1,861	1,596	202	174	2,063	1,770
Geothermal	0	163	0	6	0	169
Solar Thermal	1,783	1,783	89	89	1,872	1,872
Total	3,644	3,542	291	269	3,935	3,811



Step 4. Multicriteria Analysis

Socio-economic impact

Jobs Created per Sustainable Scenario (Socio-Economic Considerations)

	Construction		Operation		Total	
	Scenario 1	Scenario 2	Scenario 1	Scenario 2	Scenario 1	Scenario 2
Biomass Boiler	1,861	1,596	202	174	2,063	1,770
Geothermal	0	163	0	6	0	169
Solar Thermal	1,783	1,783	89	89	1,872	1,872
Total	3,644	3,542	291	269	3,935	3,811

<u>Especially for the jobs related to specific expertise, such as:</u>

- Engineers
- Operators of technical and construction equipment
- Drivers of construction vehicles
- Assistant drivers
- Workers

The construction phase of both scenarios in crucial, along with decommissioning and rehabilitation works, to ensure smooth transition for jobs and income.

- ❑ The jobs created during operation are considered as the key driver for both scenarios.
- ❑ The difference of the two scenarios are small.
- ❑ The scenario 2, of minimum risk, ensures the jobs created almost at the same level, even though weighting is smaller.

According to the Master Plan only ~30% of the jobs at stake will be transposed to the overall investment in the region

The proposed solutions creates 3.811-3.935 jobs, 270-290 being permanent jobs

Step 4. Multicriteria Analysis

Impact on income

Jobs Created per Sustainable Scenario (Socio-Economic Considerations)

	Construction		Operation		Total	
	Scenario 1	Scenario 2	Scenario 1	Scenario 2	Scenario 1	Scenario 2
Biomass Boiler	1,861	1,596	202	174	2,063	1,770
Geothermal	0	163	0	6	0	169
Solar Thermal	1,783	1,783	89	89	1,872	1,872
Total	**3,644**	**3,542**	**291**	**269**	**3,935**	**3,811**

- The jobs created during construction and operation constitute a safety net for income retain, until the rest of investment are in operation in the area.
- The investment's contribution represents 11% of the 2.400 jobs to be covered from the Master Plan's planning.

Apart from the jobs, both scenarios cover the issue of energy poverty:

- They address the energy demand
- They maintain tariff in affordable limits

Description	Unit	Value
Weighted DH tariff (Ptolemaida & Kozani)	€/MWh	40,9
	According to SDAM provisions	*37,7 & 43,5 respectively*

Almost 60M€ will remain in the area:
56M€ during construction
4M€ during operation

The multiplier for income indirect generation is between 2.7-3.1 in the area, for the specific sector.

Step 5. Selection of optimal case

2.2 Scenarios Evaluation including Environmental Considerations

The final selection of the optimum case among the two highest ranked options, was done based on the environmental performance . More specifically each green solution was classified based on its overall carbon footprint. For this purpose, an additional Environmental Performance Factor (EPF) was introduced.

Accordingly, each sustainable scenario was rated through multiplying each green solution's share with the EPF of the corresponding technology. The EPF reflect lifecycle carbon emissions and the assumed values of these indicators are relative with 1 reflecting biomass:

		Biomass	Geothermal	Solar Thermal	Final Score
Environmental Performance Factor		1	1.2	1.5	-
Final Score	Scenario 1	0.70	0.00	0.45	1.15
	Scenario 2	0.60	0.12	0.45	1.17

Conclusion

Final selected Sustainable Scenario

Min application risk corresponding to

- Biomass Boiler: 60%
- Low Enthalpy Geothermal: 10%
- Solar Thermal w/ PTES: 30%

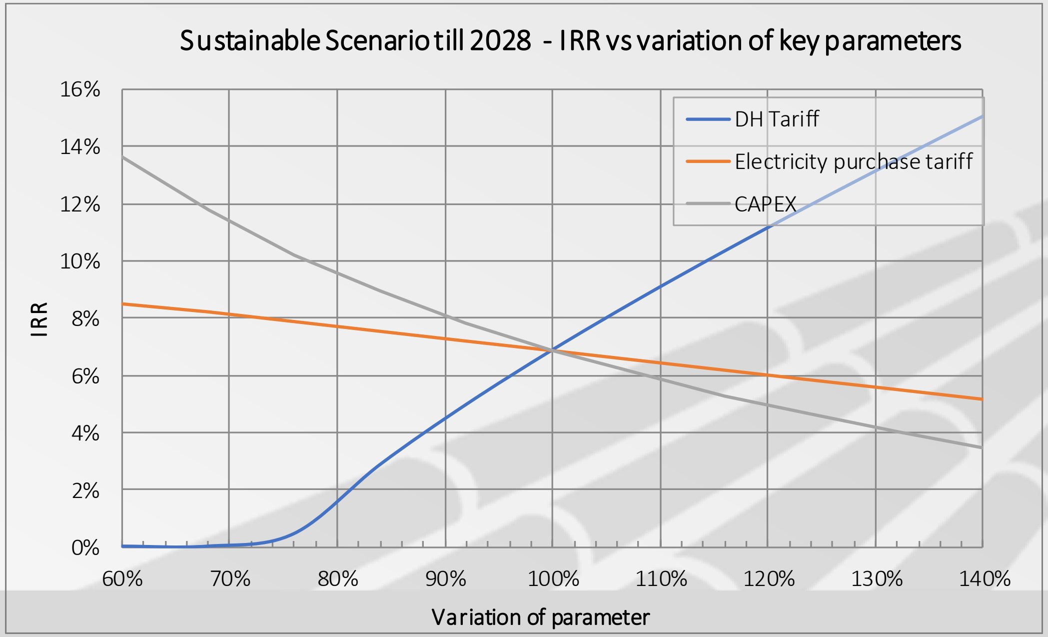
Step 5. Selection of optimal case

Key Results – Sensitivity analysis

SN	Description	Unit	Value
a	**Assumptions**		
b	Weighted DH tariff (Florina & Kozani)	€/MWhth	40.9
c	Electricity purchase tariff	€/MWhth	80.0
a	**Green DH Solution**		
b	Biomass Boiler - Demand Coverage	%	60%
c	Geothermal - Demand Coverage	%	10%
d	Solar Thermal - Demand Coverage	%	30%
e	Thermal energy to DH	GWh/yr	496
f	Demand	GWh/yr	496
g	Coverage	%	100%
h	**OPEX**		
i	Cost fo electricitty	Eur/y	3,700,729
j	Fixed costs	Eur/y	6,287,188
k	Variable costs	Eur/y	695,284
l	**Total costs**	**Eur/y**	**10,683,202**
m	**CAPEX**		
n	Investment cost	€	115,920,746
o	Grant	€	0
p	**Revenues**		
q	Total Income	€	20,290,791
r	Gross profit	€	**9,607,590**

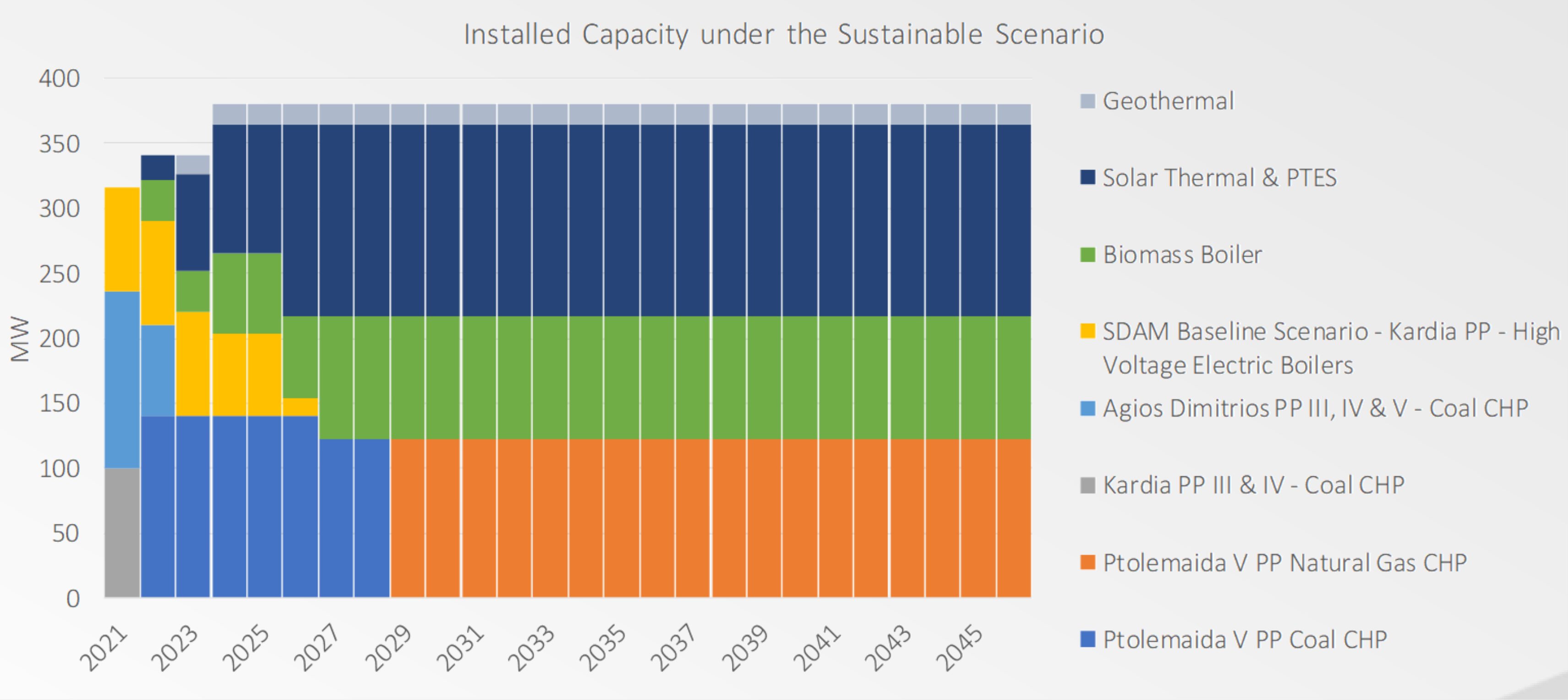
Description	Unit	Value
Net Present Value (NPV)	EUR	-26,278,800
Pay-Back Period	years	12.1
Benefit Cost Ratio (BCR)		0.8
LCOE	€/MWh	42.5
Internal Rate of Return (IRR)	%	6.89%

Notes
- Key determining parameter for viability is DH tariff and to a lesser extent CAPEX
- Variation of DH tariff by more than 10% would have a substantial impact on viability



Step 6. Implementation Roadmap

Roadmap for the Sustainable Scenario



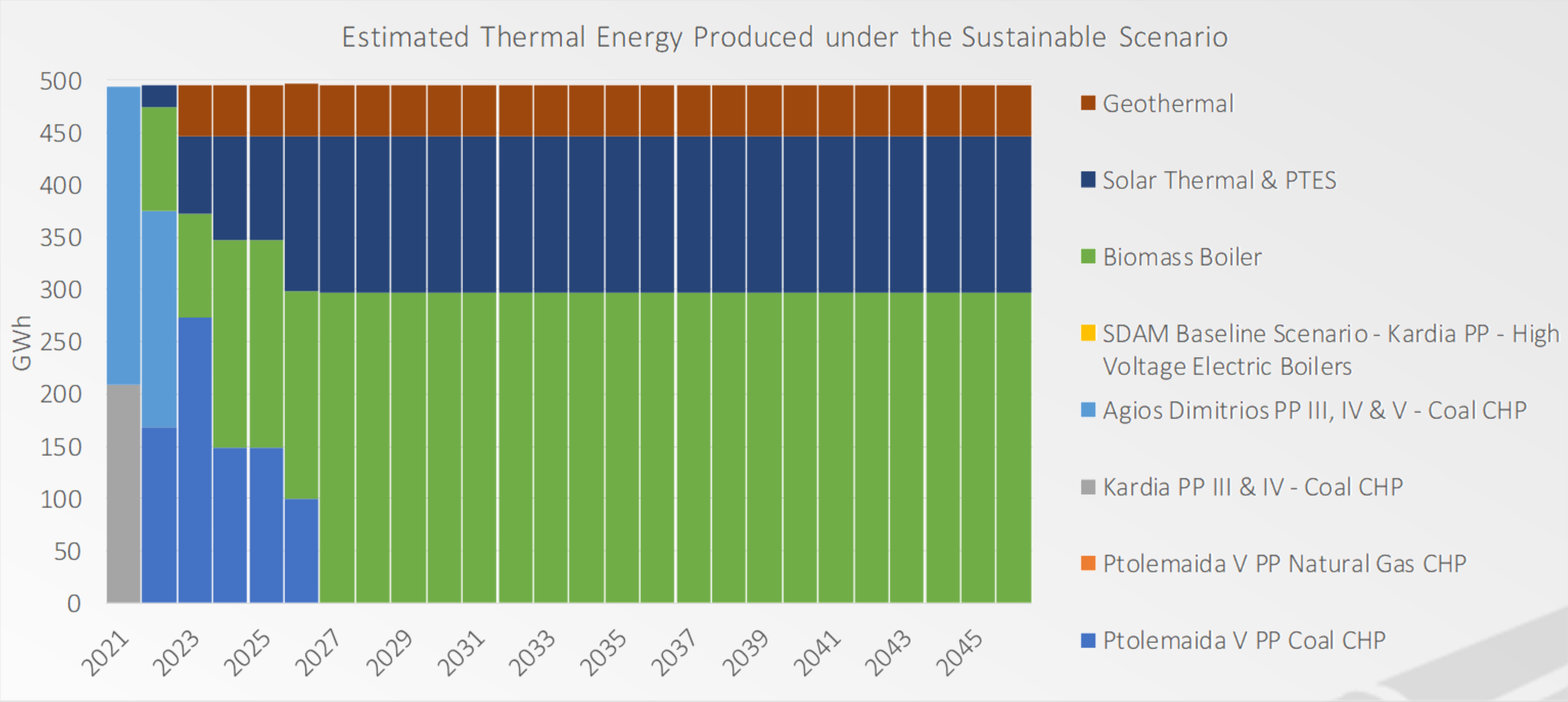
Notes

There are also additional potential green solutions that could gradually introduced into the DH hub of Western Macedonia. However, due to specific uncertainties these solutions where not assessed in the context of the present work. Such solutions include but may not limited to:

- **Biogas CHP**: Uncertainty due to limited feedstock potential and significant supply risk.
- **Hydrogen production and storage** (see “White Dragon” project): Uncertainty in terms of project feasibility and general lack of technical information.

Step 6. Implementation Roadmap

Roadmap for the Sustainable Scenario



Notes

Thermal energy demand is possible to be fully covered by green solutions from 2027 onwards. Conventional units may contribute only during periods of peak load demand.

Potential Financing Options

- Financial viability of green alternative options is marginal and sensitive to variations of several parameters including DH prices.
- Grants and other support schemes are recommended to reduce these risks.
- There is a relevant previous example on State aid support for Green DH investments

European Commission - Press release

State aid: Commission approves €150 million Romanian scheme to support investments in district heating systems based on renewable energy sources

Brussels, 6 November 2020

CASE

A new state-aid programme aimed at financial support of investments in district heating systems based on renewable energy sources has been recently approved under the EU State Aid rules of European Commission.

The main objective of this €150 million Romanian scheme will be to support the construction or upgrade of district heating systems, in line with the objectives of the Green Deal.

The European Green Deal's Investment Plan, enables Member States to use additional flexibility when it comes to the maximum amount of support that can be granted for district heating generation. The planned support will take the form of direct grants financed by EU Structural Funds managed by Romania.

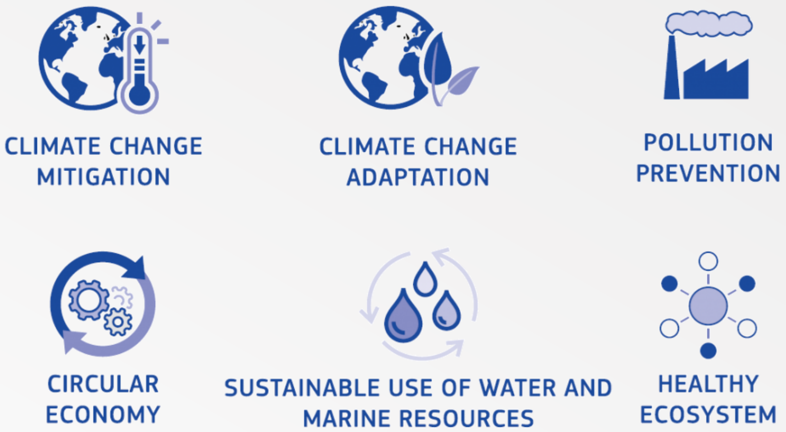
Policy Reforms – Recommendations

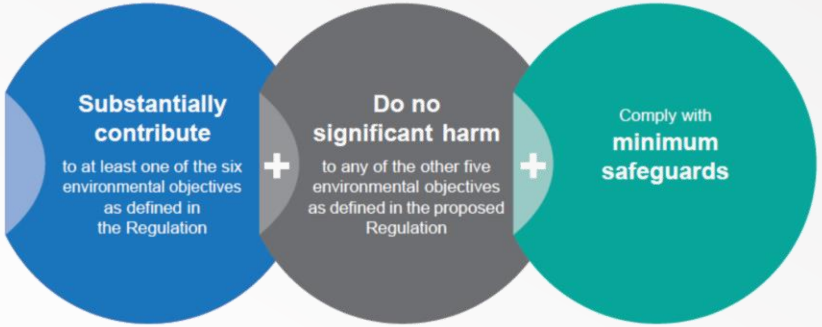
- Prioritization of green DH investments in the lignite areas as mid term option within redrafting of the "Just Transition Plan for W. Macedonia"
- Seek subsidies for RES DH investments through EU structural funds or other sources
- Reform legislation to enhance biomass utilization particularly concerning sustainable forest management and sustainable utilization of biomass from SRC.
- Development of incentive schemes to encourage agro-forestry and institutional development and promote commercial fuelwood plantations
- Assist the development of social economy organisations (cooperatives, workers cooperatives, KOINSEP, etc) to work on the biomass ecosystem
- Development of pricing policy to protect biomass suppliers
- Carry out biomass resource planning to quantify resource availability through multi-ministerial collaboration (including Ministries of Agriculture, Environment & Energy and Development)
- Develop sustainable spatial planning policy concerning biomass supply chain logistics
- Review and update min performance standards for RES-DH technologies to guarantee deployment of best practice

EU Taxonomy - Sustainable Bioenergy

"Bioenergy is peculiar among other renewable energy sources because it sits at the nexus of two of the main environmental crises of the 21st century: the biodiversity and climate emergencies."

Camia A. et al. 2021 - EC/JRC





Five-step check process to assess compliance/ eligibility

1	Identify the activities conducted by the company, issuer or covered by the financial product (e.g. projects, use of proceeds) that could be eligible.
2	For each activity, assess whether the company or issuer meets the relevant criteria for a substantial contribution e.g. < 100g CO2/kWh for heat and electricity, reducing every 5 years
3	Verify that the DNSH criteria are being met by the issuer. Investors using the Taxonomy would most likely use a due-diligence like process for reviewing the performance of underlying investees.
4	Conduct due diligence to avoid any violation to the social minimum safeguards stipulated in the Taxonomy regulation (article 13).
5	Calculate alignment of investments with the Taxonomy and prepare disclosures at the investment product level.

EU Taxonomy - Sustainable Bioenergy

Technical Screening Criteria (non-exhaustive)

Classification		Environmental contributions									
NACE Macro-sector	Activity	1. Climate change mitigation				2. Climate change adaptation	3. Water	4. Circular economy	5. Pollution	6. Ecosystems
		Type of contribution	Own performance	Enabling	Transition activity	Type of contribution	Type of contribution	Type of contribution	Type of contribution	Type of contribution
Electricity, gas, steam and air conditioning supply	Production of Heat/cool from Bioenergy (Biomass, Biogas, Biofuels)	Substantial contribution	x		x	DNSH	DNSH	DNSH	DNSH	DNSH

Facilities operating above 80% of GHG emissions-reduction in relation to the relative fossil fuel comparator set out in RED II, increasing to 100% by 2050, are eligible

Identified and Managed Risks related to water quality/consumption. Water use/conservation management plans have been developed in consultation with relevant stakeholders

Production of Biomass, Biogas and Biofuels: Only feedstocks listed in Part A of Annex 9 EU REDII eligible

EIA & SEA in accordance with EU Directives

Emissions (SO_2, NOx, dust, CO, Mercury, HCl, HF) for biomass in mg/Nm^3 for large combustion plants

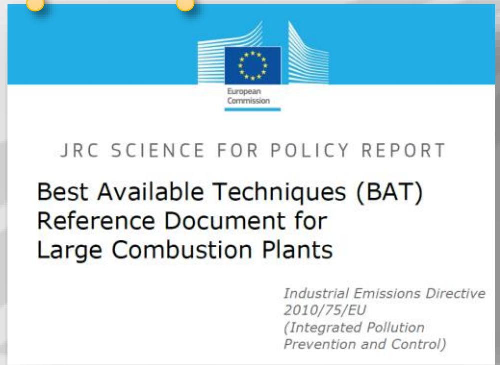
Classification		Environmental contributions					
NACE Macro-sector	Activity	1. Climate change mitigation	2. Climate change adaptation	3. Water	4. Circular economy	5. Pollution	6. Ecosystems
		Type of contribution	Type of contribution	Type of contribution	Type of contribution	Type of contribution	Type of contribution
Electricity, gas, steam and air conditioning supply	Production of Heat/cool from Bioenergy (Biomass, Biogas, Biofuels)	DNSH	Substantial Contribution	DNSH	DNSH	DNSH	DNSH

The economic activity must reduce all material physical climate risks to that activity to the extent possible and on a best effort basis.
The economic activity and its adaptation measures do not adversely affect the adaptation efforts of other people, nature and assets.
The reduction of physical climate risks can be measured

Depending on the primary objective of the activity, refer to:

- Screening criteria for adapted activities
- Screening criteria for an activity enabling adaptation

Users of the Taxonomy should identify and explain which criteria they are responding to.



Scenarios' Comparison - Life Cycle Emissions

Assumptions – Conversion factors

Fuel Type	tCO2/MWhth	Source
Coal (Lignite)	0.336	JRC - 2015
Natural Gas	0.232	JRC - 2015
Electric Boiler	0.989	TEE-TCG
Biomass - CN	0.017	JRC - 2017
Biomass - NCN	0.184	JRC - 2017
Solar Thermal	0.989	TEE-TCG
Geothermal	0.989	TEE-TCG

	kg/MWh			
	N. Gas	Coal	Biomass	
			Lower	Upper
CO2	232.31	336.10	17.00 (CN)	184.00 (NCN)
CO	0.06	0.32	0.18	0.54
NOx	0.14	0.71	0.18	0.72
SOx	0.00	4.01	0.03	0.14
PPM	0.01	4.25	0.13	0.25

CN: Carbon Neutral | NCN: Non-Carbon Neutral

Sabouni P. et al. 2014

IrBEA 2016

Directive (EU) 2015/2193

Directive (EU) 2008/50/EC

Life-cycle analysis for Biomass needs to account for emissions form Harvesting & Transport of feedstock. It is assumed that all transportation distances are within 80-km radius in W. Mac.

Table 8. Comparison of forest biomass supply life cycle environmental impacts.

Sources	GHG Emissions kg CO_{2eq}/tonne			Fossil Energy Demand MJ/tonne		
	Harvesting	Transport	Total	Harvesting	Transport	Total
Sonne, 2006 [17]	17.4	38.2	55.6		n/a	
Gonzalez-Garcia *et al.*, 2009 [18]		n/a		283–340	226–100	509–440
Slade *et al.*, 2009 [8]	23.8	9.2	33		n/a	
Valente *et al.*, 2011 [19]	15.2	10.2	25.4	204	155	359
Handler *et al.*, 2014 [21]	17.8	22.5	40.4	233	263	496
This study	17.4	5.2	22.6	218	59	277
Assumed for calculations:	**18.3**	**5.2**				

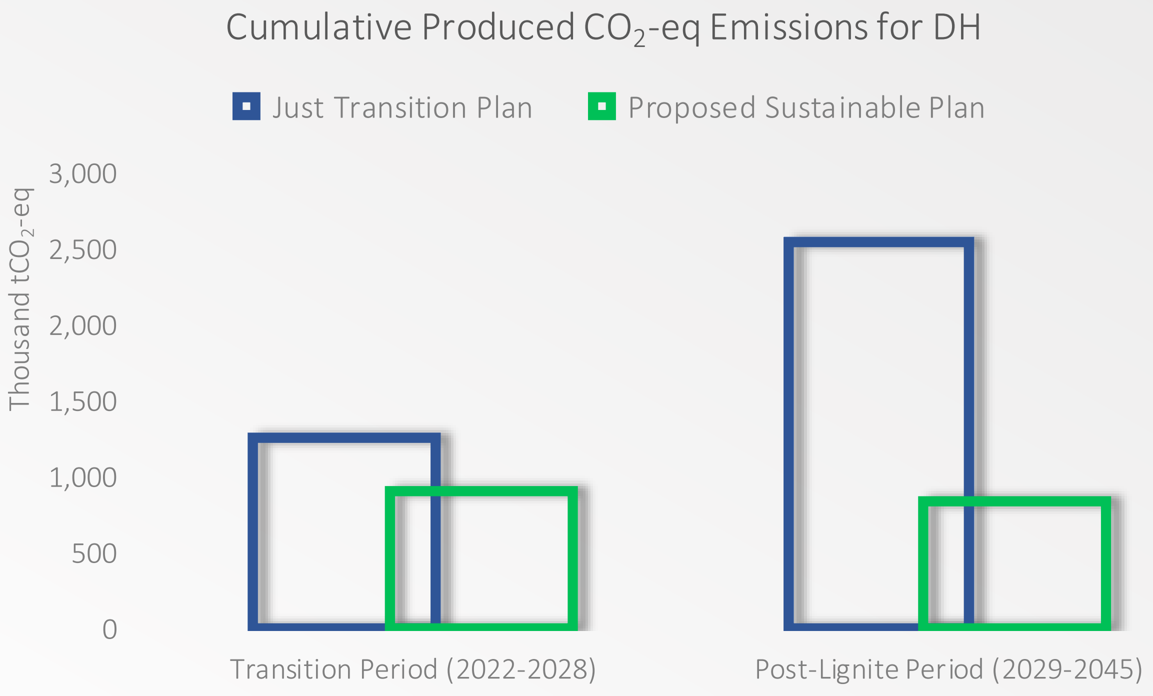
Zhang, F et al. (2015) - Life-Cycle Energy and GHG Emissions of Forest Biomass Harvest and Transport for Biofuel Production in Michigan.

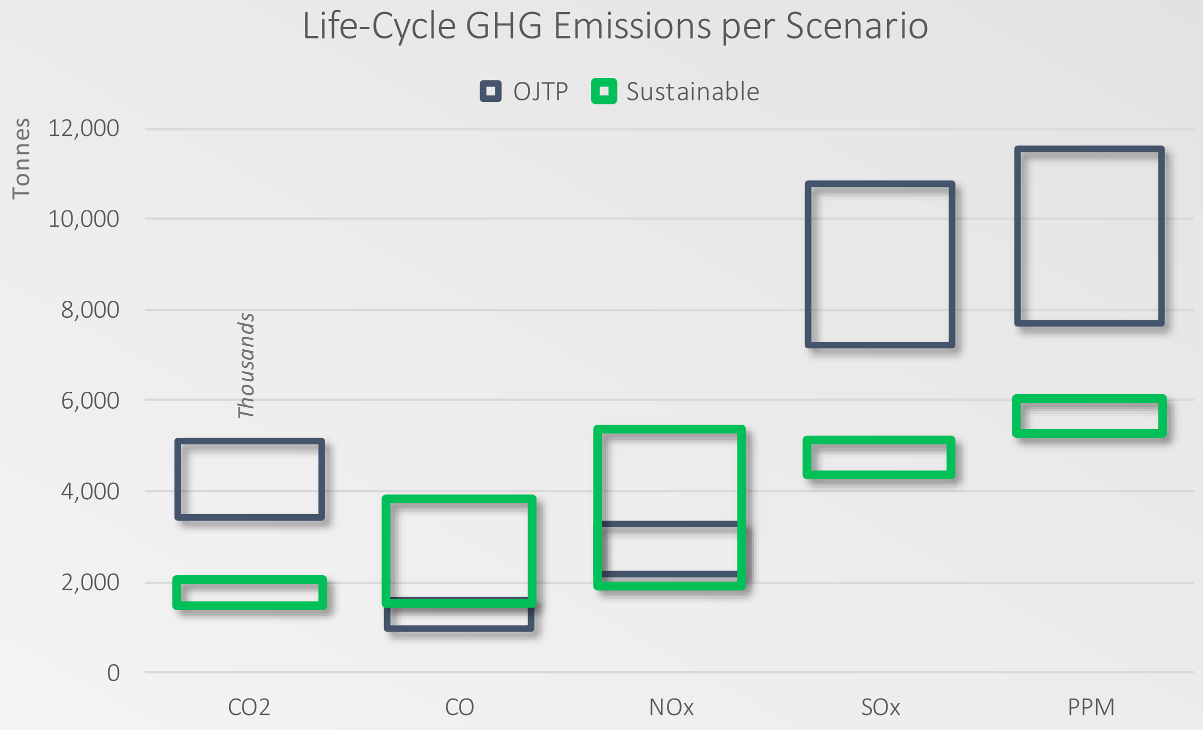
<u>The principal emissions which may be released from biomass combustion are:</u>

- PM: salts, soot, condensable organic compounds (COCs), volatile organic compounds (VOCs) & intermediate products – e.g. tars and PAHs
- NOx: nitric oxide (NO), nitrogen dioxide (NO2) & nitrous oxide (N2O)
- COx: carbon monoxide (CO) & carbon dioxide (CO2)
- SOx: sulphur dioxide (SO2) & sulphur trioxide (SO3)
- Dioxins/Furans
- Of these, PM & NOx are most relevant when considering biomass combustion.

Scenarios' Comparison - Life Cycle Emissions

Results





Overall Evaluation

The solution proposed for the district heating network of W. Macedonia provides an environmentally sustainable, reliable, cost efficient and realistic solution that will produce better outcomes compared to the Just Territorial Development Plan. The expected benefits are:

- **Environmental**
  - Emissions during the lifecycle are generally lower, as shown in the study.
  - Enhanced protection against forest fires, resulting from the removal of remnant forest biomass, always under the guidance of the local forest authorities, in the context of sustainable forest management plans.
- **Economic**
  - Strong impact on local income and job creation potential.
  - Cost for heating for consumers remains at the same level.
- **Social**
  - Active local engagement in the provision of district heating services to the local communities, combined with sustainable forest management are equally important to the expected employment output.
  - The development of local cooperatives and SMEs is expected to boost the entrepreneurial spirit of all actors supporting the move of Western Macedonia to the post-coal era, thus strengthening social cohesion and ownership of the transition process. Creating synergies between the district heating system, as an important service to the community, the associated environmental benefits and the positive impact in reducing rural poverty fosters a win-win situation for this impoverished region.

PROJECTS WORLDWIDE

REVIEW 2016

REACHING MORE THAN 110 COUNTRIES

CONNECTING OUR WORLD

Thank you !!!

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Azerbaijan
Barbados
Belgium
Belize
Benin
Bolivia
Bosnia & Herzegovina
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Burkina Faso
Burundi
Cambodia
Cameroon
Chile
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Colombia
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Croatia
Cuba
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Czech Republic
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