VALUE CE-IN

Potenziale di un Innovativo Processo di Trattamento Idrotermico dei Fanghi di Depurazione

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Coordinatore

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ENEA Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile

Partner

PROAMBIENTE

LEAP Laboratorio Energia e Ambiente Piacenza

Terra & Acqua Tech

Progetto cofinanziato dalla Regione Emilia-Romagna (bando POR - FESR 2014 - 2020)

POR FESR EMILIA-ROMAGNA 2014/2020

UNIONE EUROPEA Fondo europeo di sviluppo regionale

Regione Emilia-Romagna

- LEAP x VALUE CE-IN
- Sewage Sludge Disposal Routes
- Hydrothermal Processes
- Benchmark vs. Novel Sewage Sludge Incineration Processes
- Conceptual Design Scenarios
- Techno-Economic Analysis
- Conclusions and Future Perspectives

LEAP x VALUE CE-IN

Laboratorio Energia e Ambiente Piacenza

Agrosistemi s.r.l.

Background

- → The general project objective is the optimization of the value chain related to the treatment of municipal and industrial wastewater by applying circular economy principles and proposing high TRL solutions and Key Enabling Technologies (KET).
- → VALUE CE-IN: within circular economy framework, water resources preservation, nutrients recovery and sludge disposal, increasing WWTP energy efficiency and introducing new business models.
- → LEAP activities: Phase 3 – part 3 - evaluation of Hydrothermal Treatments for Sewage Sludge conversion in secondary raw materials minimizing plant waste output.
- → Partnership with Agrosistemi s.r.l. for HTD pilot plant development and testing.

Objectives

- → Techno-economical analysis of HTD process as pre-treatment for mono-incineration and power production.

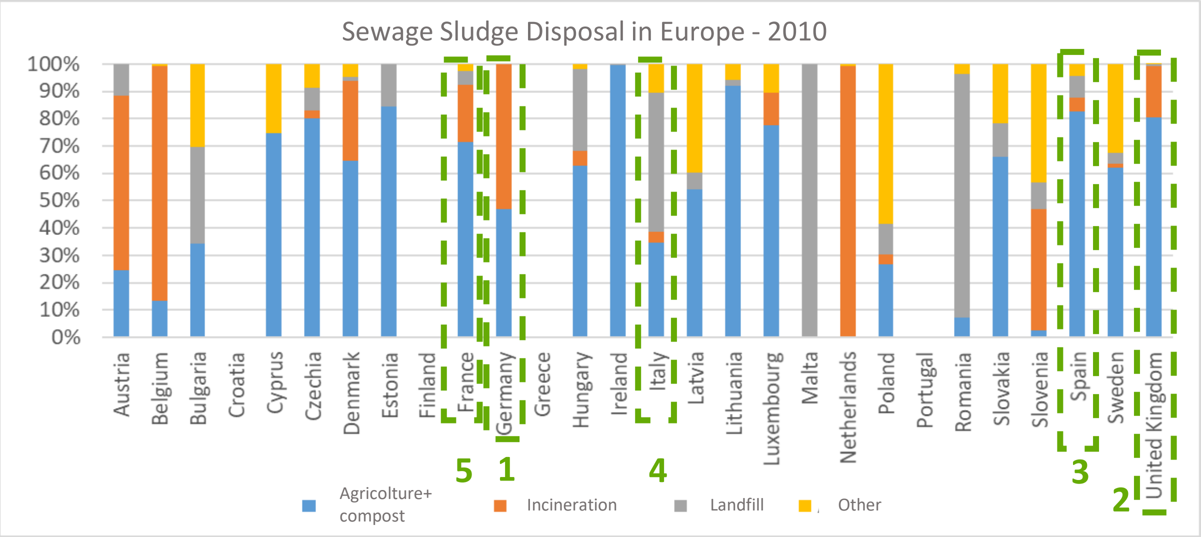
Sewage Sludge Disposal Routes

1. Agricolture
European, National and Regional Laws discourage this route -> health concerns.
Data 2010: still preferred route by the 5 main sewage sludge producers
2. Incineration
Thermal treatment is the preferred solution when agricultural re-use is not possible.
3. Landfill
Italy's extensive use of landfilling is an anomaly in Europe

Incineration is extensively applied in EU. Netherlands totally relies on it (100%), followed by Belgium (87%) and Germany (53%).

Sludge incineration → high energy demand for sludge drying due to significant residual water content (~70-78%w/w)

Novel process → Higher DM content @ dryer inlet (at least +10-30%w/w DM increase exploiting hydrothermal technology)



Source: Eurostat

Hydrothermal Processes

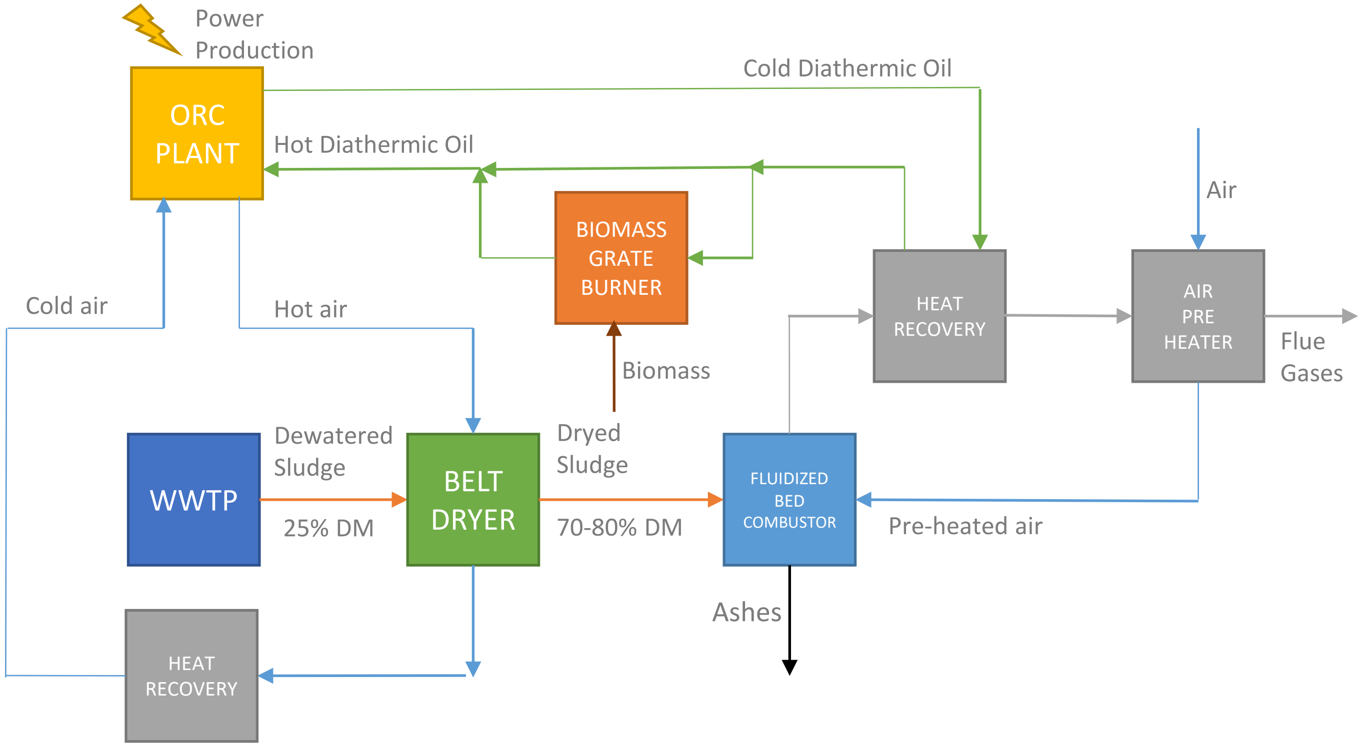
Sewage Sludge

Hydrothermal Liquefaction (HTL)
250 – 370 °C |180 - 250 bar | 5 – 60 min
High pressure – short time reaction;
→ **Bio-crude**

Hydrothermal Carbonization (HTC)
180 – 250 °C |15 – 25 bar | 1 – 8 h
Low pressure – long time reaction;
→ **Hydrochar**

Hydrothermal Dewatering (HTD)
210 – 230 °C |20 bar | 15 – 30 min
Low pressure – short time reaction;
→ **Dewatered Cake**

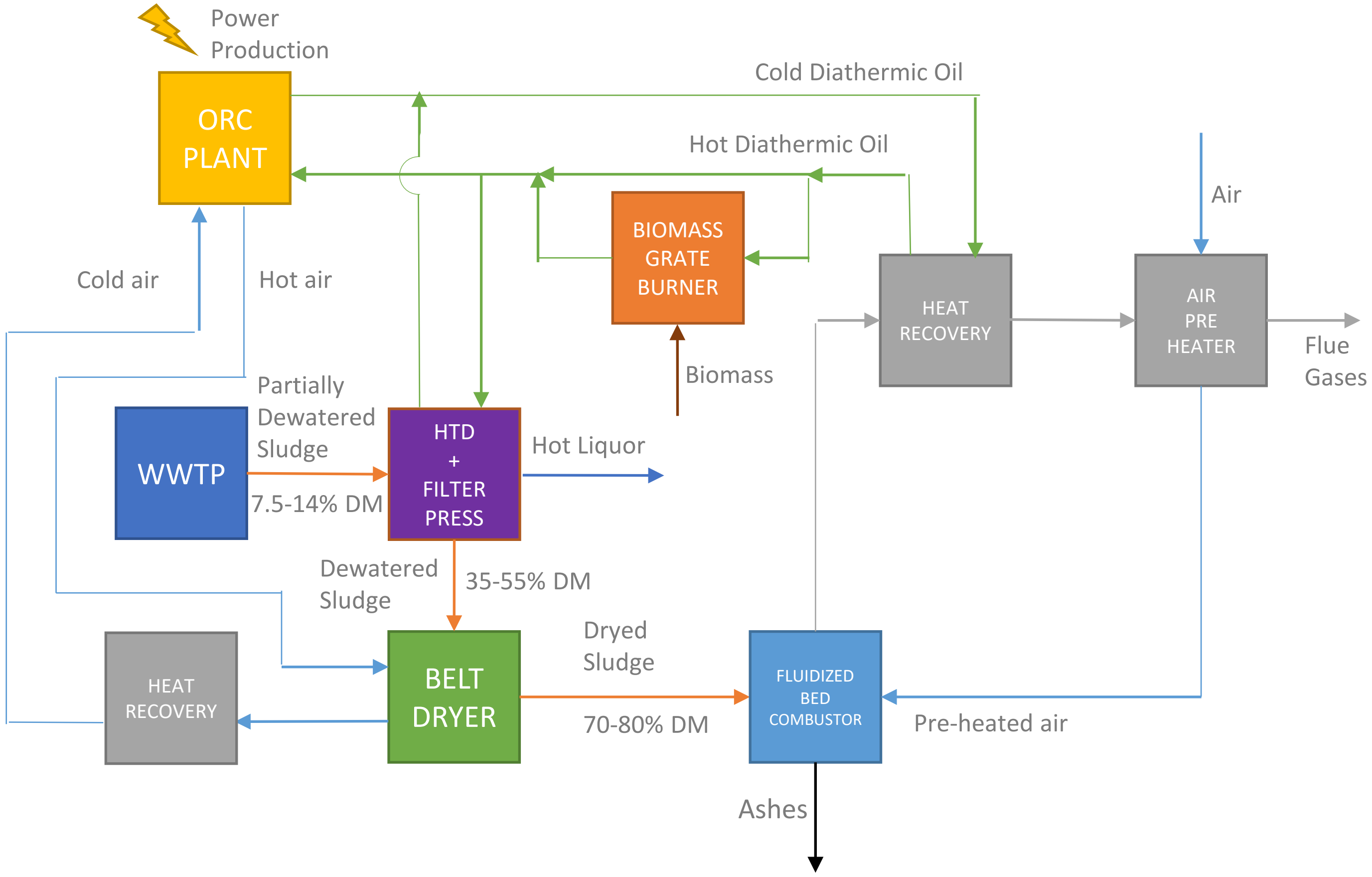
Benchmark vs. Novel Sewage Sludge Incineration Processes



Benchmark Incineration Process

- **Sewage sludge** from waste-water treatment plant **dewatered** and conveyed to **belt dryer**;
- Dry sludge **incinerated** in a dedicated fluidized combustor
- Flue gas from the combustor → **thermal integration** with ORC via a dedicated diathermic oil circuit
- ORC → power production and thermal duty for the belt dryer

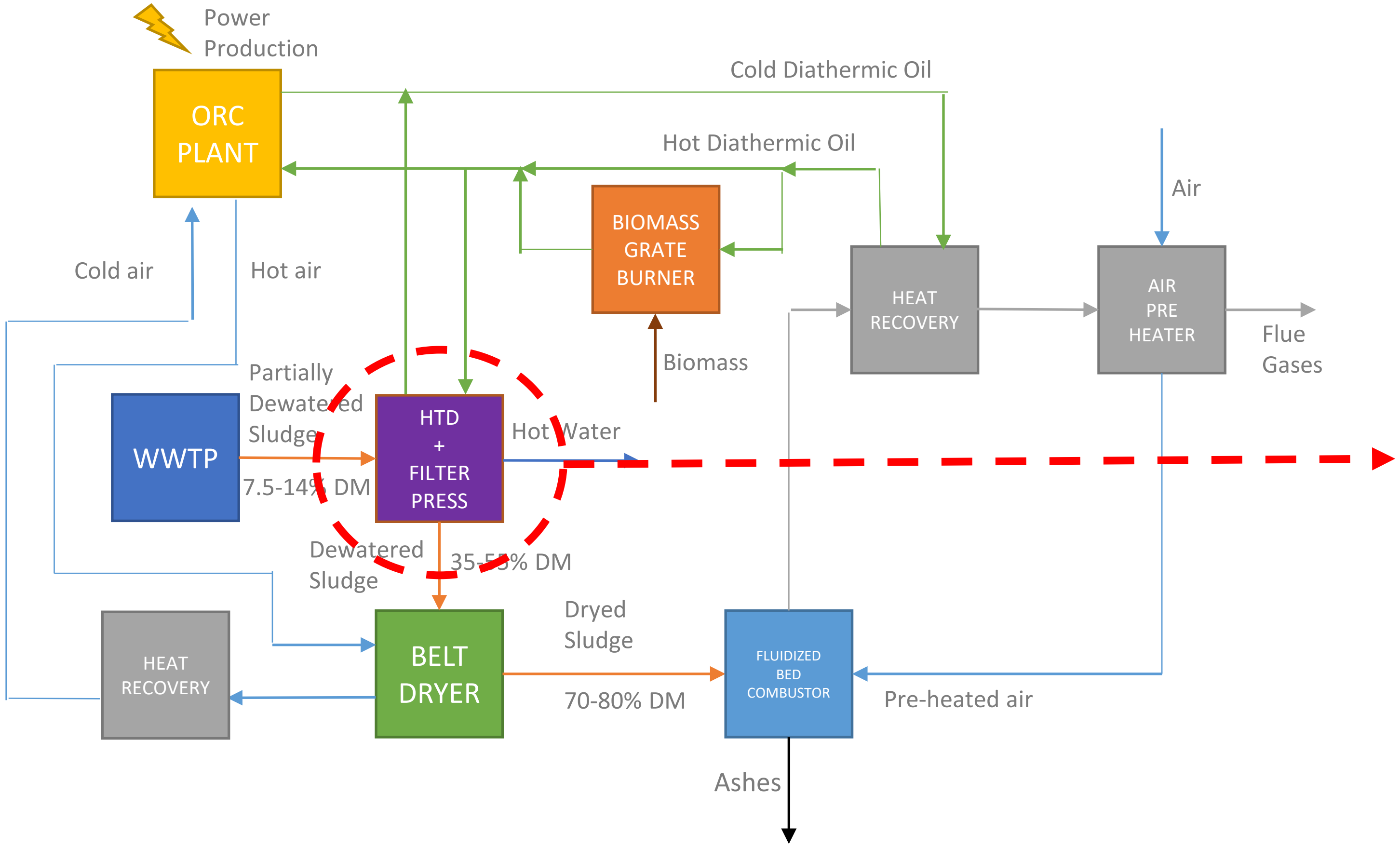
Benchmark vs. Novel Sewage Sludge Incineration Processes



Novel Incineration Process

- **Sewage sludge** from waste-water treatment plant partially **dewatered** and conveyed to **HTD**;
- **HTD** → increase DM content up to 35-55 % (filter outlet)
- Dry sludge incinerated in a dedicated fluidized combustor
- Waste heat recovery from combustor flue gas via dithermic oil circuit
- Diathermic oil → thermal duty for HTD process and ORC
- ORC → power production and thermal duty for the belt dryer

Benchmark vs. Novel Sewage Sludge Incineration Processes



Conceptual Design Scenarios

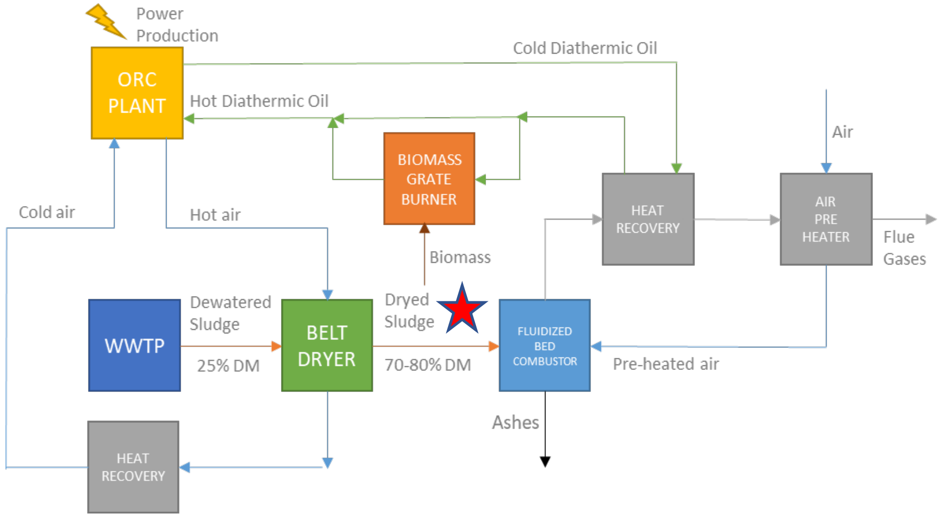
Benchmark process performance evaluated based on **required DM% at dryer outlet** (70%,75%, 80%) ★

Novel process performance evaluated using **three key parameters**:

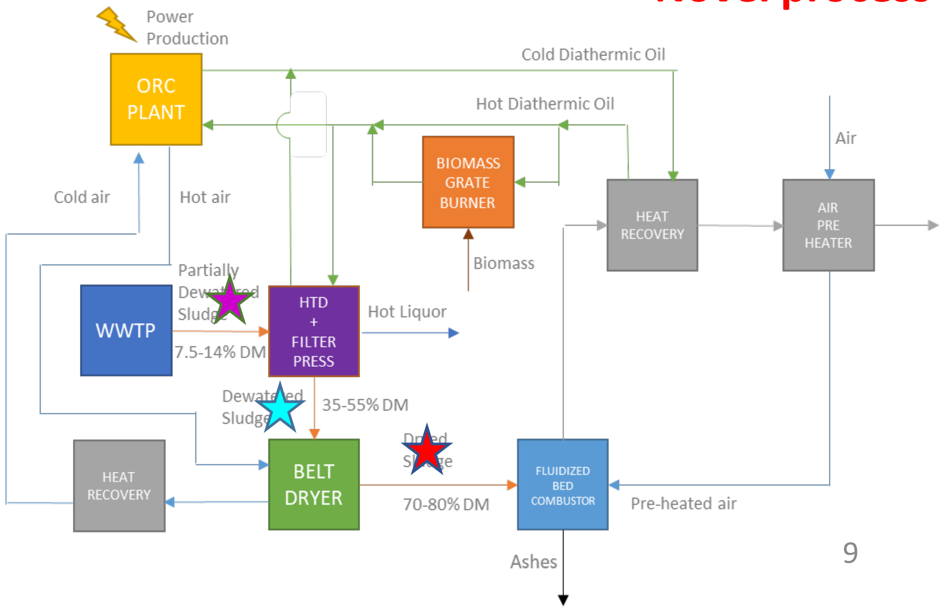
- **DM% at HTD inlet** (7.5%, 12.5%, 14%) ★
- **DM% at HTD outlet** (35%, 45%, 55%) ★
- **DM% at dryer outlet** (70%,75%, 80%) ★

Leading to the evaluation of **27 scenarios + 3 benchmark**

Benchmark process



Novel process



Techno-Economic Analysis

Benchmark Process – Processed feed and Energy duties

Parameter	Unit of Measure	Value		
% Dry Matter out dryer	*%*	*70%*	*75%*	*80%*
Belt Dryer Thermal Need	MW	3,89	4,02	4,13
Condensation Power needed	MW	3,97	4,10	4,22
ORC Net Electric Power	kW	696	720	740
Thermal Input from Sludge combustion	MW	2,32	2,40	2,48
Thermal Input from Biomass combustion	MW	2,41	2,48	2,54
Biomass input	t/h	0,99	1,03	1,05
Sludge Input	t/h	1,37	1,37	1,37
Auxiliaries power consumption	kW	189	191	192

Table 23. Benchmark System overall plant energy balance results.

- Process design: 1.37 t/h sludge (7500 h/y)
- ↑ORC size with dryer thermal duty (function of DM%)
- Additional thermal input from biomass combustion ≈ thermal duty from sludge incineration

Techno-Economic Analysis

Benchmark Process – Economic analysis

CAPEX				
% Dry Matter out dryer	*%*	*70%*	*75%*	*80%*
Belt Dryer	k€	4886	4997	5085
Fluidized Bed Combustor	k€	5379	5851	6316
Centrifuge	k€	250	250	250
ORC power unit	k€	2910	2979	3039
Biomass Grate Burner	k€	3837	3936	4024
Subtot	k€	17262	18013	18714
BOP	10% of Subtot	1726	1801	1871
Total Plant Cost (TPC)	k€	18988	19815	20585
Capital Charge Ratio (CCR)			15%	
Yearly Quota of TPC	k€/y	2848	2972	3088

Table 25. Benchmark plant Capex composition.

OPEX				
% Dry Matter out dryer	*%*	*70%*	*75%*	*80%*
Avoided costs (-)				
Net Thermal Production (-)	k€	-	-	-
Net Electric Production (-)	k€	-783	-810	-833
Auxiliaries Electric consumption (+)	k€	213	214	216
Ash disposal (+)	k€	884	884	884
Personnel (+)	k€	100	100	100
Fuel cost (+)	k€	373	385	395
Flue gas cleaning consumables (+)	k€	17	17	17
O&M TPC (+)	k€	475	495	515
Total Opex	k€/y	1278	1285	1293
Yearly Capex+Opex		4126	4257	4381
Disposal Cost	**€/t DM**	**402**	**414**	**426**
	€/t TQ	**100**	**104**	**107**

Table 26. Benchmark Operative costs and resulting sludge disposal costs.

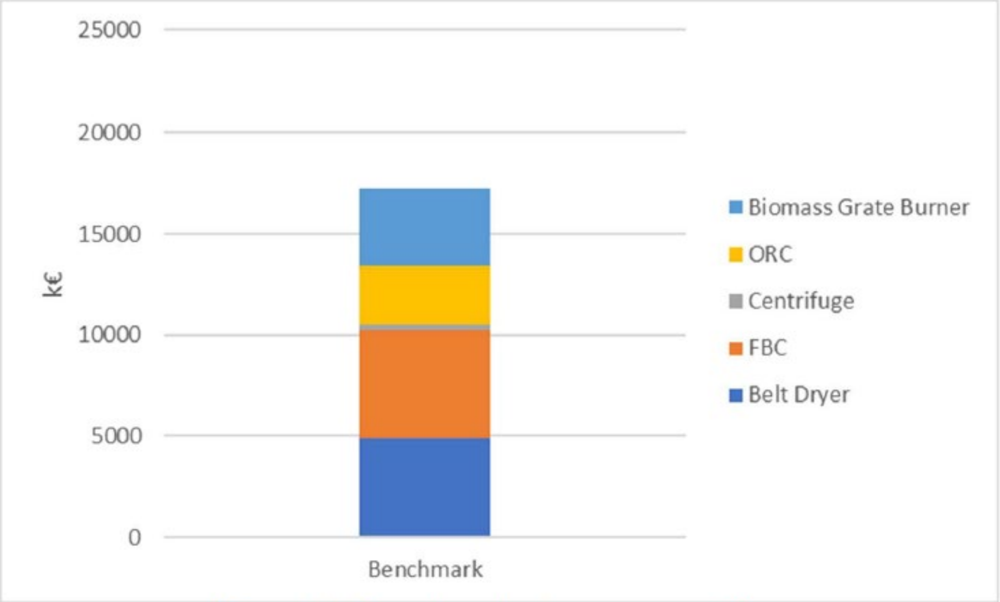
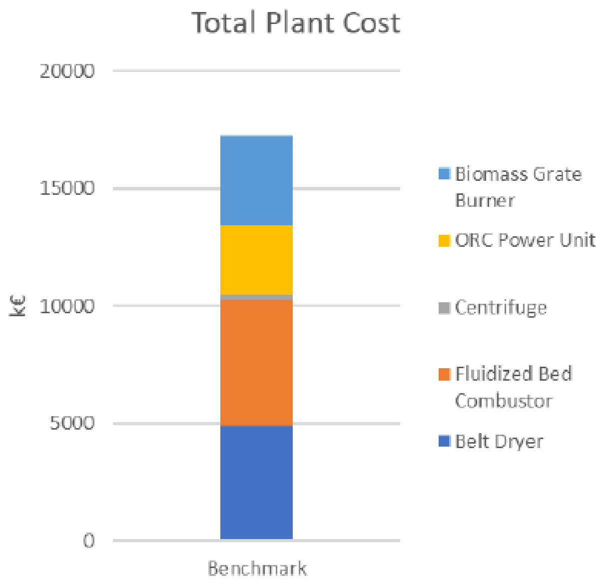


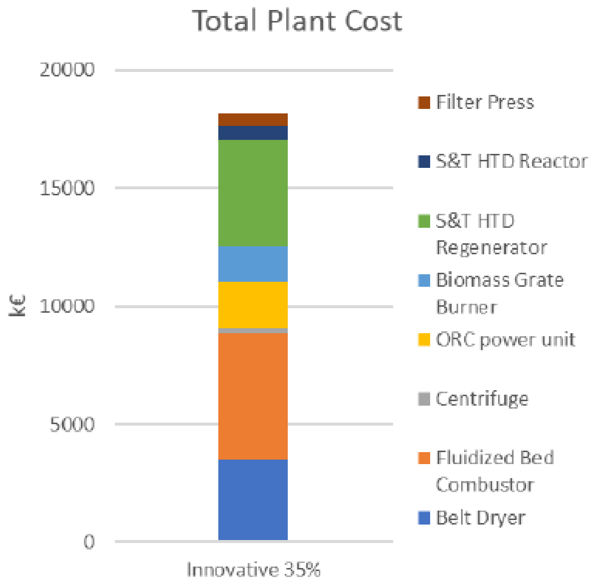
Figure 27. Benchmark Capex composition.

- ↑Disposal Cost with ↑DM% dryer outlet
- Disposal Cost: **100-110 €/t$_{TQ}$**

Techno-Economic Analysis

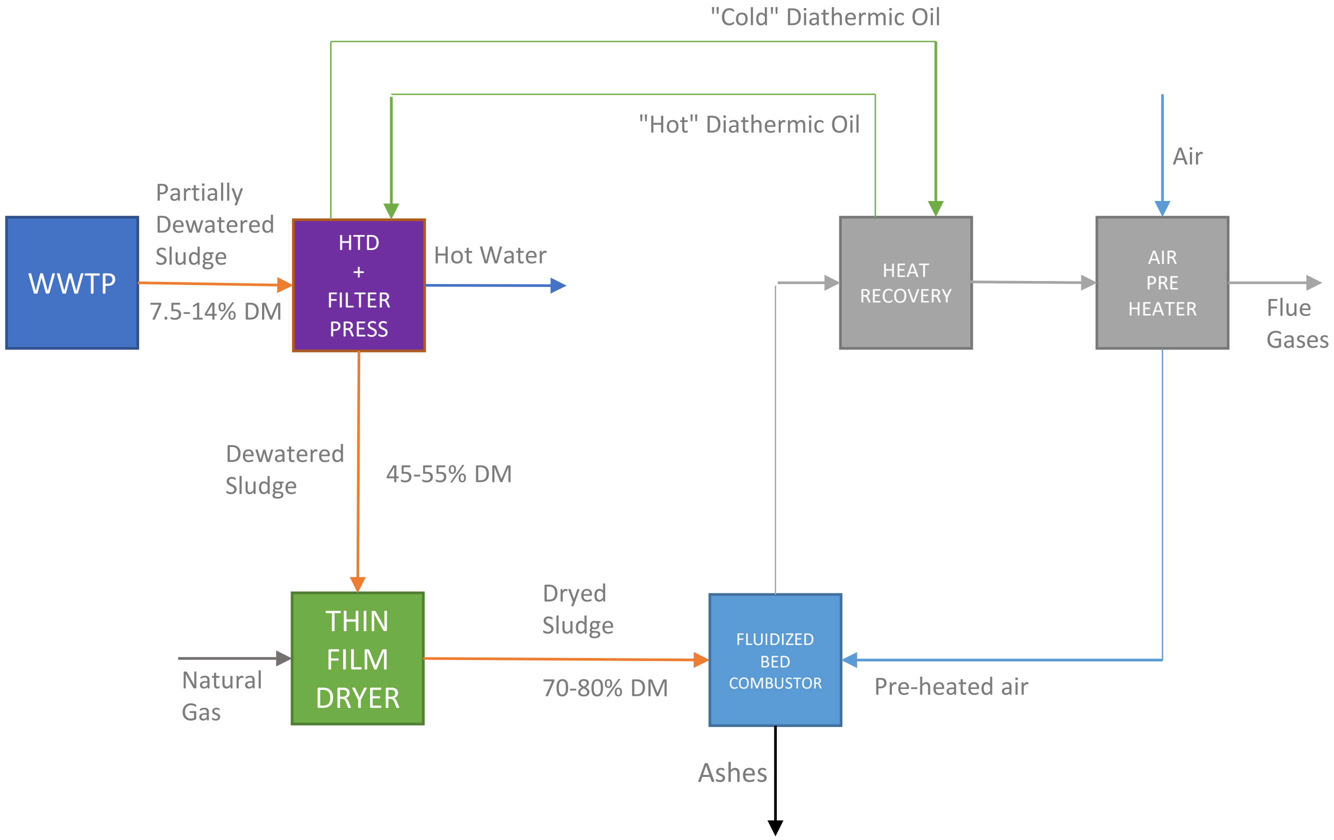
Novel Process – Economic analysis





- Costs comparable with benchmark process
- ↑ DM% at HTD outlet = ↓ ORC size
- ↑ DM% at HTD outlet = ↓ biomass inlet
- Novel process re-design for high DM% at HTD outlet

Benchmark vs. Novel Sewage Sludge Incineration Processes

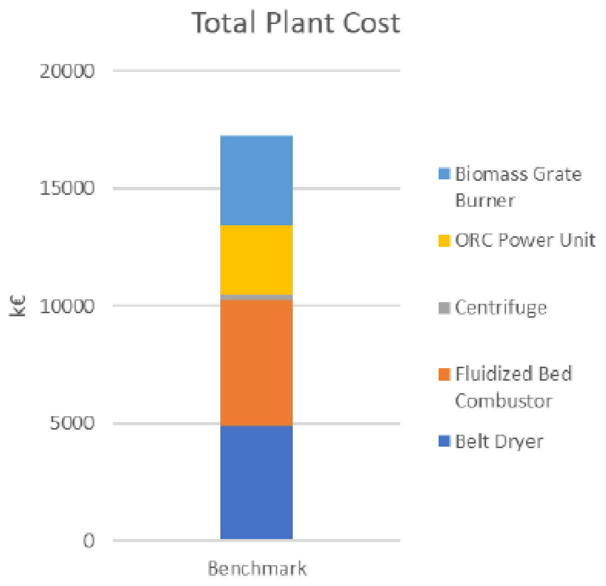


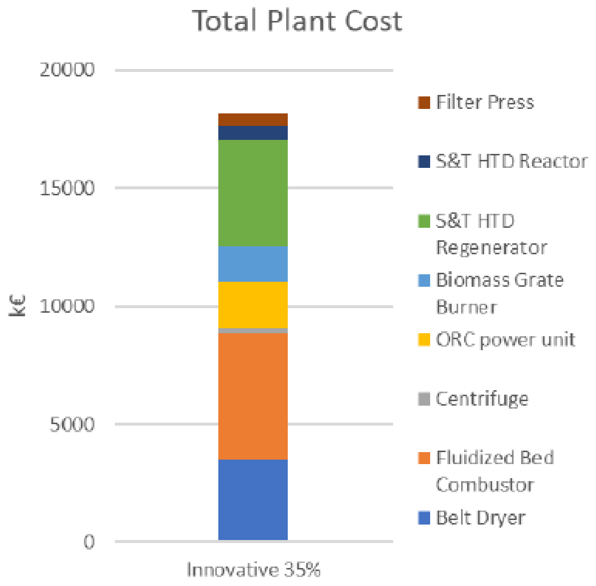
Novel Incineration Process – re-designed

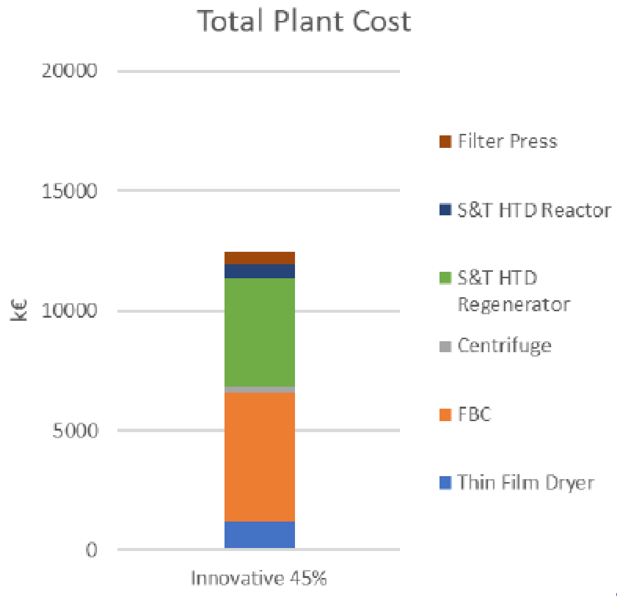
- Sludge dewatered to **at least 45% DM**
- ORC too small for economic sustainability -> removed
- No need for biomass extra-input -> removed
- Belt dryer replaced with thin film dryer -> **thermal integration** between HTD and flue gas from FBC only

Techno-Economic Analysis

Novel Process – Economic analysis

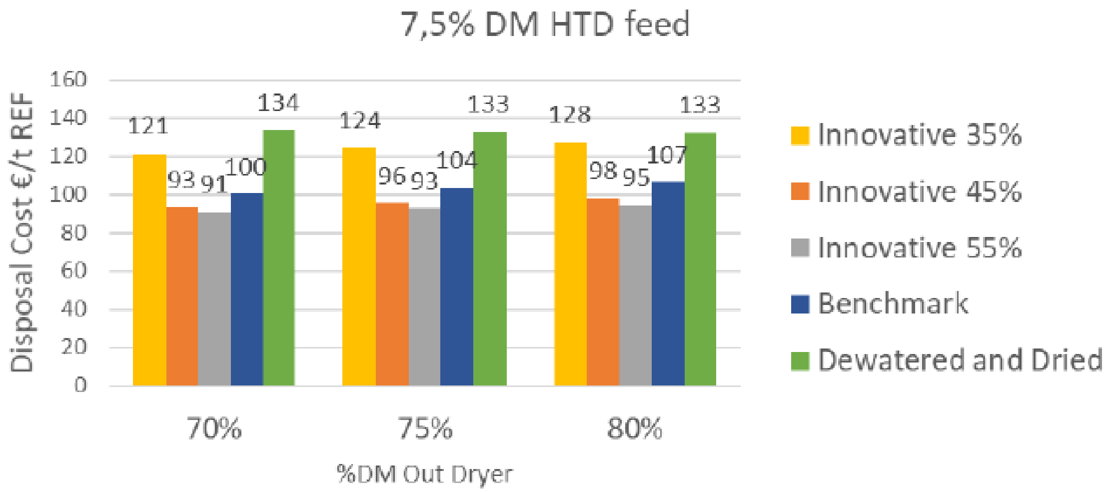






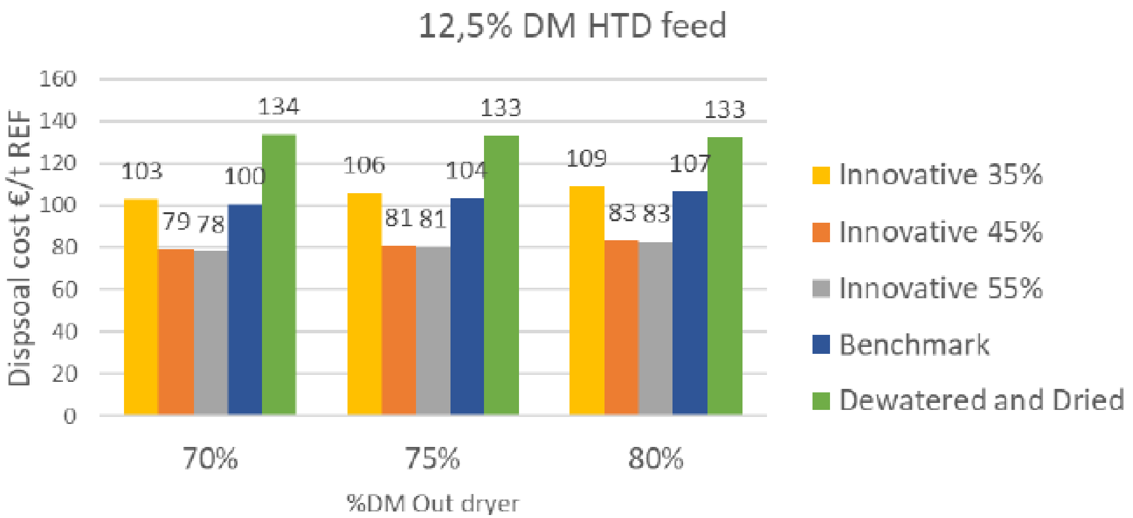
Simplified plant configuration -> up to 25% Capital Cost savings!

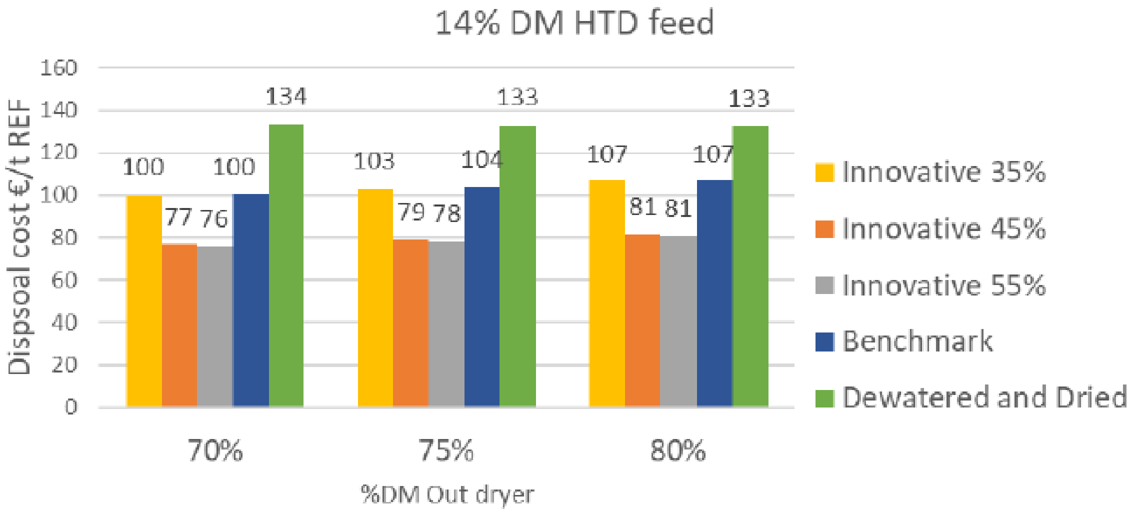
Techno-Economic Analysis



FINAL RESULTS – DISPOSAL COSTS

- Specific costs for a ton of sludge at 25%DM (REF)
- **Dewatered and Dried**: a facility with only dewatering and drying capability - a disposal cost of ~133 €/t_{ref}
- Up to 20% in disposal cost reduction achievable





Conclusions and Future Perspectives

Conclusions

→ HTD process can be effectively integrated with the mono-incineration process in a cost-effective way (-25% with respect to the benchmark process)

→ Threshold: 45% DM at HTD outlet, already reached in the lab tests

Future Perspectives

→ Complete integration: recycling of hot water stream from HTD to WWTP head (feasibility to be verified)

→ Pilot Plant from Agrosistemi to be modified -> continuous operation

→ Further experimental campaign to support pre-commercial scale plant design

Grazie per l'attenzione!

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