The HTW gasification technology and its application to solid waste materials

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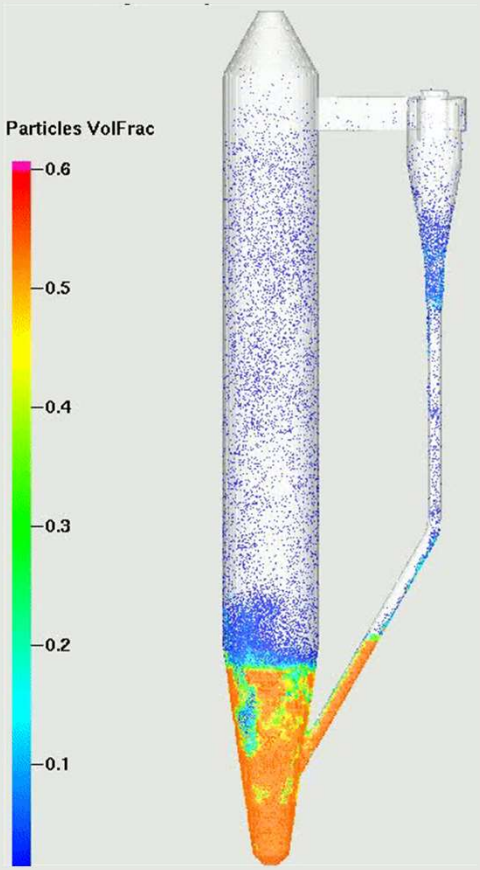
GIDARA® ENERGY

Who we are

GIDARA® ENERGY

HTW® Technology

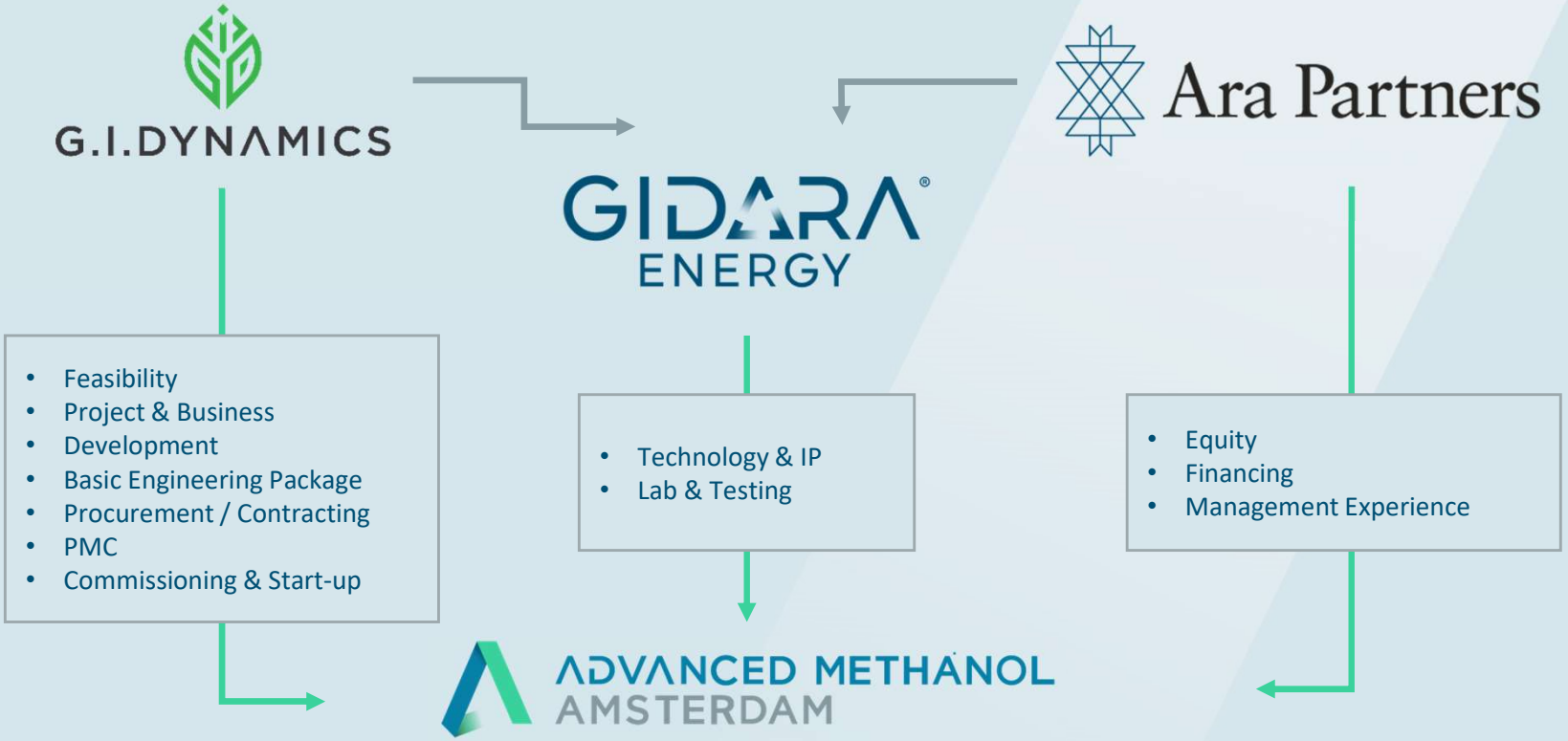
Simulation & Experiment for HTW®2.0 Design



Advanced Methanol Amsterdam & Rotterdam Plants

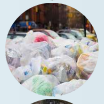
GIDARA Energy structure

GIDARA is jointly owned by **Ara partners,** US private equity firm, and **G.I. Dynamics**, Dutch engineering and project development firm, for the sole purpose of building Renewable Gasification to (Bio-)Fuel plants.



Ability to Convert Wide Range of Feedstock into High Value Products

Material Feedstock Flexibility

- Wood Waste 
- Sewage Sludge 
- Municipal Solid Waste 
- Non-Recyclable Plastics 
- Waste Paper 
- Agricultural Residue 
- Construction & Demolition Waste 

Adaptable and Cost-Effective Gasification Technology

GIDARA Energy's process and commercially proven & mature HTW® technology plus adapted purification design allows a broad range of feedstocks
(with minor to no incremental CAPEX)

Multiple End Product Applications

Road Transport Fuels

- Green Gasoline
- Biomethanol
- Renewable Diesel
- Green H2
- Renewable Natural Gas (CNG, LNG)
- Bio-mmtpa

Marine Fuels

- Biomethanol
- Bio-Ammonia
- Bio-DME
- Renewable Natural Gas (CNG, LNG)

Sustainable Aviation Fuels

High Growth End Markets (e.g. Chemicals)

Technology proven and applied for more than 10 yrs and with wide range of feedstock

- ✓ **Experience in pressurized fluidized bed gasification since 1978**
- ✓ **+ 600 Mio Euro:** - Investment in development of HTW till 2022
- ✓ **3 commercial plants:** - Successfully built and operated
- ✓ **+10 years:** - Operational time of a single plant.
- ✓ **+91% Availability:** - Average availability in 10 year
- ✓ **+5% Extra availability:** - Can be increased by process improvements
- ✓ **Existing Testing facility:** - Recent successful test on all mixtures of RDF and biomass waste

1970s

Rheinbraun & ThyssenKrupp developed the pressurized version of the gasifier known as the High Temperature Winkler (HTW) process

Key reference plant

1986 - 1997

Commercial plant
at Berrenrath, Germany

Input → **Output** Methanol

Purpose/learnings of the plant
- ✓ Methanol production from syngas
- ✓ Long-term use of RDF + plastic sources, feedstock flexibility
- ✓ Pressure range 10 bar

1988 - 1994

Commercial plant
at Oulu, Finland

Input → **Output** Ammonia

Purpose/learnings of the plant
- ✓ Produce ammonia from syngas
- ✓ Utilisation of peat and waste wood as feedstock, feedstock flexibility
- ✓ Pressure range 10 bar

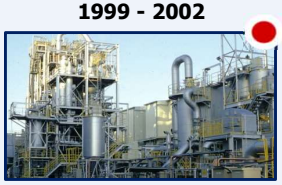
1989 - 1992

High pressure plant
at Wesseling, Germany

Input → **Output** Syngas

Purpose/learnings of the plant
- ✓ Sustainable HTW gasification operations under 25 bar

1999 - 2002



Demonstration plant
at Niihama, Japan

Input → **Output** Syngas

Purpose/learnings of the plant
- ✓ Utilizing direct municipal solid waste as feedstock to produce syngas

Key reference plant

2020 - current

Demonstration plant
at TU Darmstadt, Germany

Input → **Output** Syngas

Purpose/learnings of the plant
- ✓ Feedstock testing and continuous research and development on HTW technology
- ✓ Full production including methanol

Fossil fuels (coal, lignite)

Biomass (incl. waste wood)

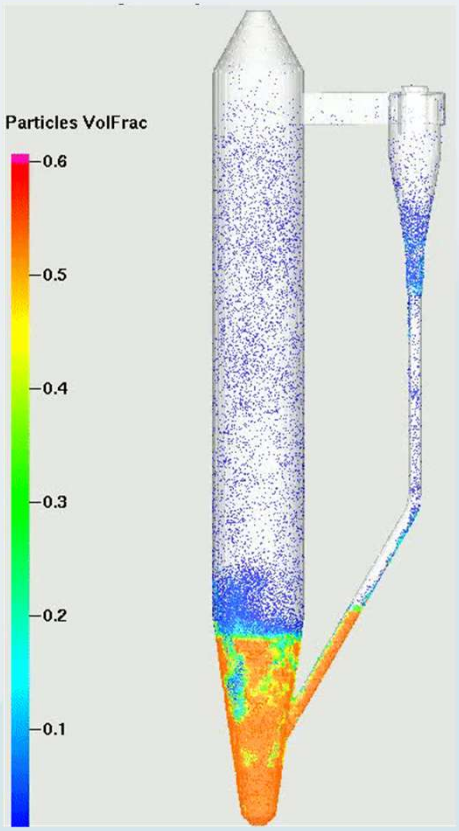
Waste

Today

Proven track record of multiple HTW projects, strong market demand and regulatory tailwinds make HTW technology an economically viable option for biofuels

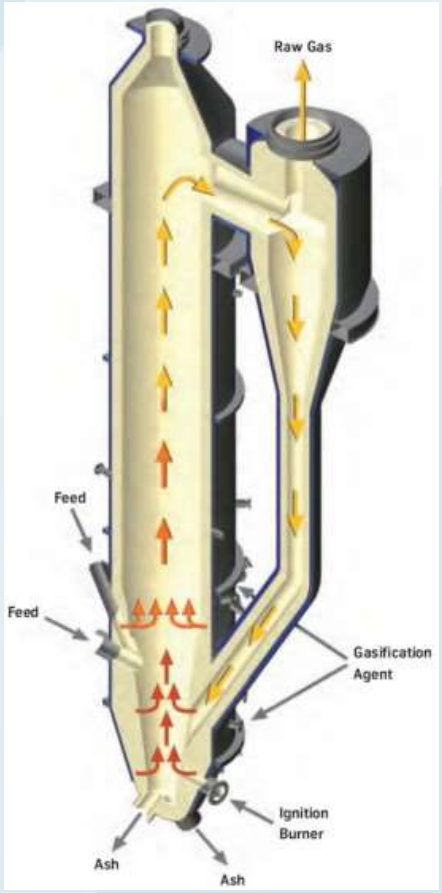
Superiority of HTW®2.0 Gasification Technology

- **Less O_2 consumption** compared to Entrained flow gasification process;
- High flexibility for **operational load** over a wide range of operating conds.;
- **Simple** start-up and shut-down procedures;
- **No undesired by-products** in the syngas, incl. tars: phenols and HMW hydrocarbon;
- **Proven and robust sub-systems** such as: feeding system, waste heat recovery, dry dust removal



HTW®2.0 Fluidized Bed Gasifier

- Pressurized Bubbling Fluidized Bed
- Agents: Air or O_2 , Steam and CO_2
- Injected via nozzles at several levels along the Gasifier
- Thermal zones: Fluidized Bed: 750-1000 °C
  Freeboard: 900-1200 °C
- Pressure: 1-30 bar (40 bar technically feasible)
- Feedstock rate: up to 160 t/h
- Carbon Conversion: over 95%
- High Cold Gas Efficiency (over 85%)
- Designed availability: 8000 h/y (approx. 91%)



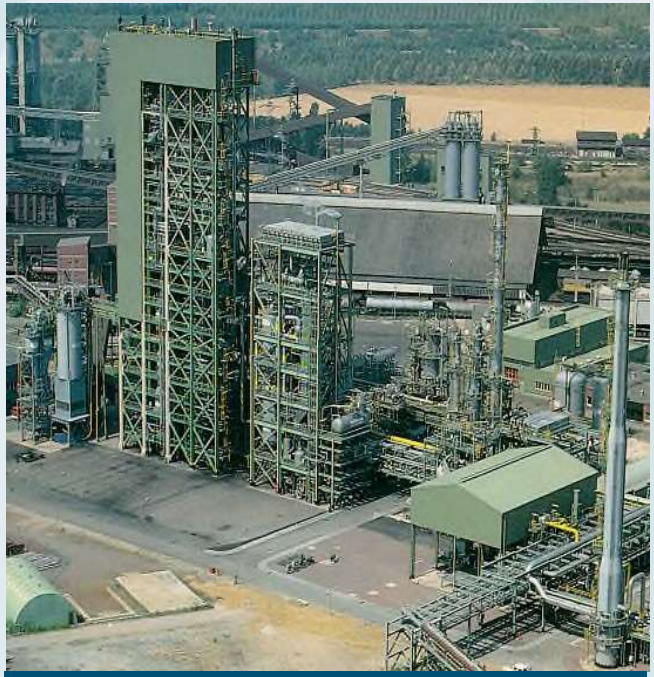
- Proven experience with wide range of feedstock incl. low rank coal, biomass, MSW-driven wastes (RDF, SRF), sewage sludge, peat, etc.

Experience from Key Reference Plant (Berrenrath-Germany)

HTW™-to-Methanol Plant (10 bar, 720 tpd) – HTW™ Unit

Feed:	25 t/h
Operating pressure:	10 bar
Syngas ($CO+H_2$) production:	38,000 Nm3/h
Cold gas efficiency:	85 %
Carbon conversion:	95 %
In operation:	1986 - 1998
Methanol Production:	300 tpd
Total operation:	76,000 h
RDF*:	15,195 h
Type of feedstock used:	lignite, DSD-plastic residue, sewage sludge, SRF, Waste Wood, Dioxin /furan-loaded cokes from waste incineration

*Excluding other waste combinations such as sewage sludge, wood, peat, etc.



HTW Demonstration Plant Berrenrath (1986-1997)

Experience from Key Reference Plant (Berrenrath-Germany)

HTW™-to-Methanol Plant (10 bar, 720 tpd) – HTW™ Unit

- Syngas Quality:

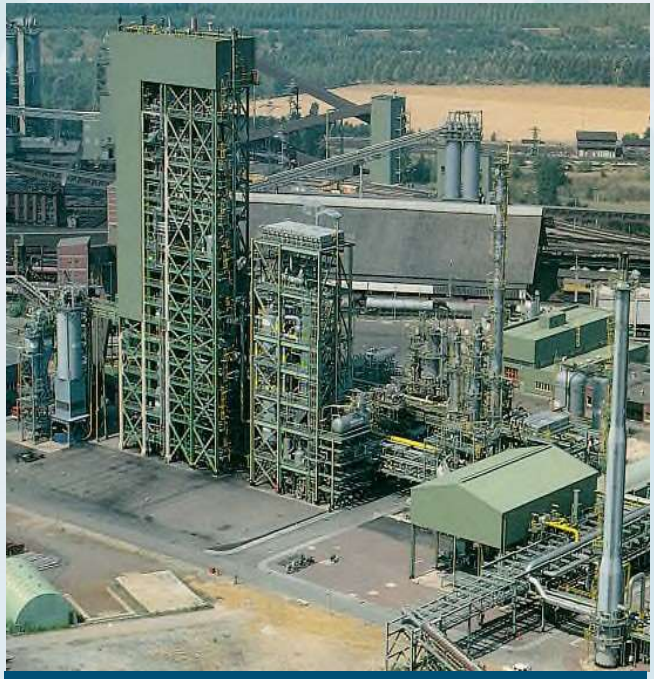
H_2O	17.5 vol%
CH_4	3.3 vol%
CO	31.6 vol%
CO_2	18.2 vol%
H_2	29.2 vol%
N_2	0.2 vol%
H_2S	560 ppm

- Specific Oxygen Consumption:

  O_2 Nm^3/kg coal, daf – 0.39

- Specific Syngas Production:

  $CO+H_2$ – 1500 Nm^3 /t brown coal, daf

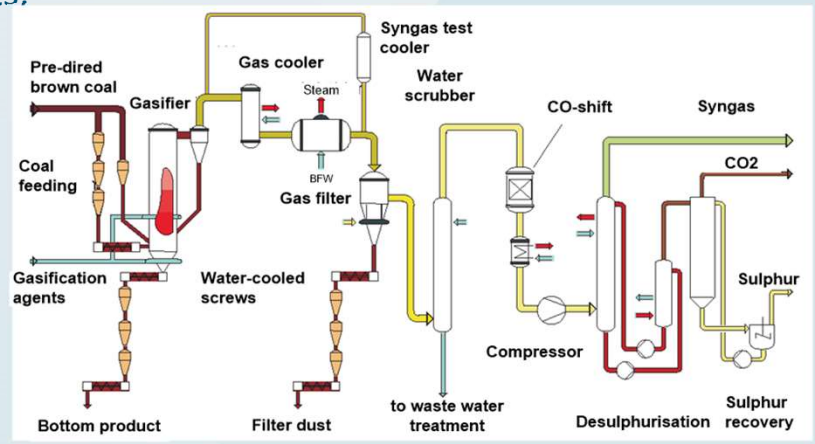


HTW Demonstration Plant
Berrenrath (1986-1997)

Experience from Key Reference Plant (Berrenrath-Germany)

HTW™-to-Methanol Plant (10 bar, 720 tpd) – Essential Components and Process Steps

- Dried brown coal entry via 3-lock hopper system by means of screws and/or pneumatic conveying,
- Gasification at 10 bar with O2/steam and some recycled CO2,
- Raw gas cooling by water tube and fire tube cooler in series,
- Dry de-dusting using ceramic filter candles in a warm gas filter unit at approx. 270°C,
- Water scrubbing to remove ammonia and chlorine, contribute to water vapor saturation at approx. 130°C and as a protective device against dust penetration for the downstream catalysts,
- Sulfur-resistant CO conversion and HCN/COS hydrolysis,
- Converted gas compression to approx. 37 bar,
- Rectisol scrubbing for H2S and CO2 removal,
- Delivery of synthesis gas via pipeline to DEA Wesseling
- Sour gas treatment to process CO2 and elemental Sulphur.



Experience from Key Reference Plant (Berrenrath-Germany)

Waste co-gasification: DSD – plastic residual pellets

- **Short term tests ->** 2-days long test with 40% residual materials (9 t/h) have been carried out.
  To check the existing equipment and operation behavior.
- **Long-term tests –>** 1-year long tests with variation between 1-5 t/h DSD mixed plastics. (approx. 25% of total load)
  To detect and eliminate weak points
- **Continuous operation -** with mostly 2-3 t/h DSD plastics. (approx. 15% of total load) in order to be able to keep the benzene within approved limits. (legal approval for up to 5 t/h DSD)
  To improve profitability
- Total 25 000 tons

Year	In operation	Coal + Coke + MSW	Plastic Waste	O2 consumed	Syngas produced	Syngas delivered for MeOH production
	hours	t	t	10^3 m³	10^3 m³	10^3 m³
1986**	3 068	60 189		19 500	47 186	29 360
1987**	3 732	90 844		31 292	116 069	98 833
1988**	5 878	150 396		52 467	195 951	187 402
1989	7 394	170 656		60 923	242 666	239 029
1990	5 897	144 433		49 991	200 700	197 657
1991	6 929	161 519		55 556	224 553	221 413
1992	6 821	168 262		56 634	231 725	231 710
1993	7 984	127 325	676	43 613	175 391	172 092
1994	7 668	158 722	3 295	55 680	223 700	221 747
1995	6 295	94 954	4 372	31 440	129 573	126 807
1996	7 307	124 839	6 283	45 629	183 003	177 385
1997	7 528	104 453	10 142	39 373	160 274	154 055
Total	76 500	1 556 592	24 731	542 097	2 130 791	2 057 489

Experience from Key Reference Plant (Berrenrath-Germany)

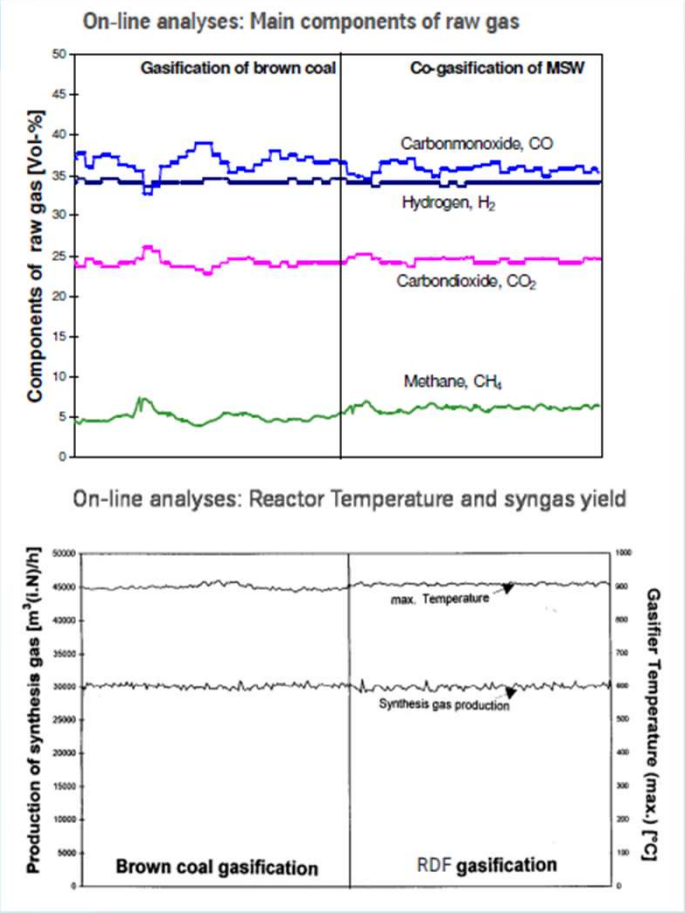
Waste co-gasification: various waste materials

- **Dried sewage sludge -** tests were carried out in the summer of 1993 and in autumn 1994. A total of 504 t of dried municipal sewage sludge with admixing rates of 3-5 t / h were used.
- **Loaded cokes** - In a series of tests in 1997, about 400 t of coke from flue gas cleaning systems of MSW incinerators in Kassel and Rotterdam was gasified
- **SRF pellets -** In the autumn of 1997, in the framework of EU-Thermie Project, around 1,050 t of processed municipal solid waste were gasified together with brown coal.
- **Waste Wood** – tests with approx. 21 t of shredded waste wood were performed. A conveyance experiment with wood only in a cold system showed that the pressurization in a lock hoppering system is problematic due to the building of bridges and holes in the vessels. Thus, for mono-gasification of wood in pressurized systems, it is recommended to take some pre-treatment steps of the wood (such as palletization, for instance).

Experience from Key Reference Plant (Berrenrath-Germany)

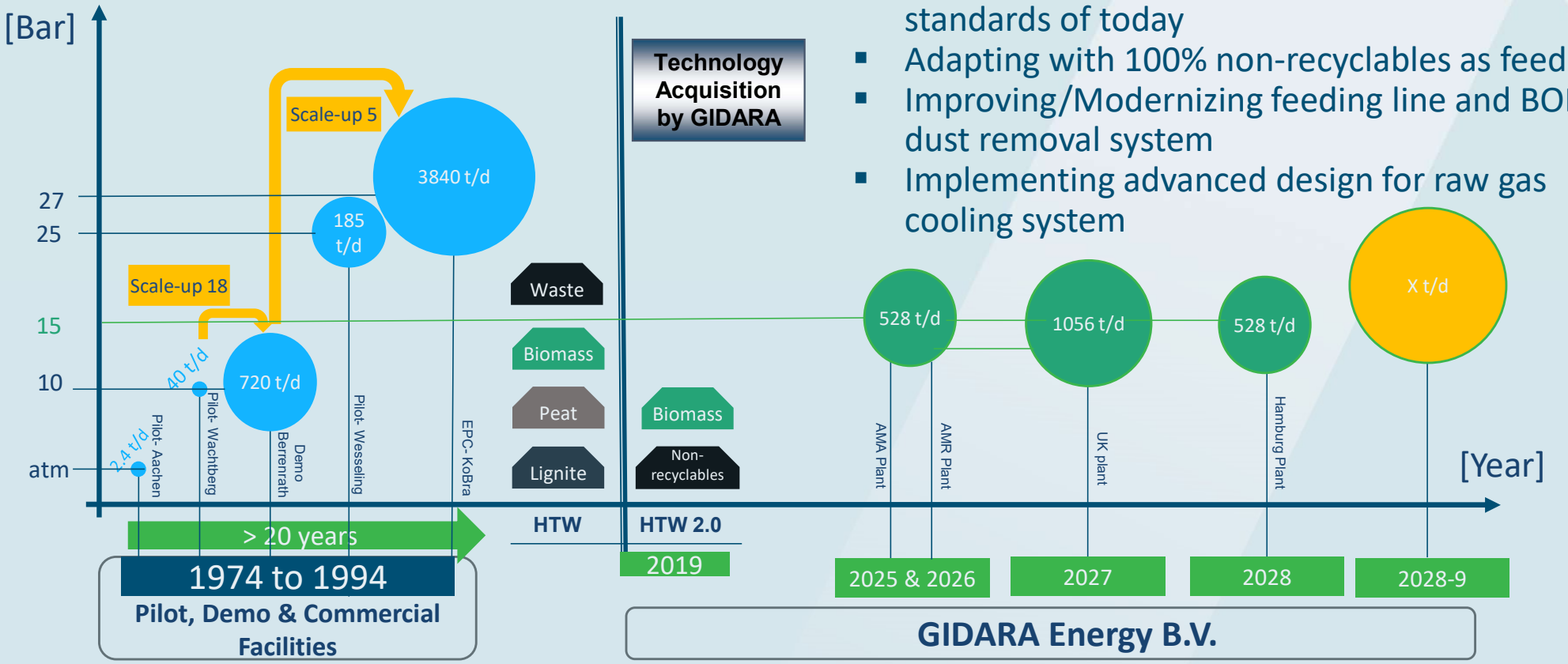
Waste co-gasification: Summary

- pre-treatment/upgrade of MSW to SRF and RDF, make them a suitable feedstock for HTW™ process;
- Trouble-free storage, conveying and feeding under pressure of RDF pellets into HTW gasifier;
- No adverse effect on operation of gasifier and downstream processes
- No significant change in syngas composition;
- Insensitivity of the HTW process to fluctuations in the calorific value of the raw materials
- Emission limits are met successfully;
- Dioxins and furans are destroyed by gasification effectively. No dioxins can be formed in gasifier (no oxygen)



Development of GIDARA Energy's Fluidized bed Gasification Process to HTW® 2.0

- Upgraded to the technological and environmental standards of today
- Adapting with 100% non-recyclables as feedstock
- Improving/Modernizing feeding line and BOP and dust removal system
- Implementing advanced design for raw gas cooling system



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HTW® Pilot Plant in operation since 2015

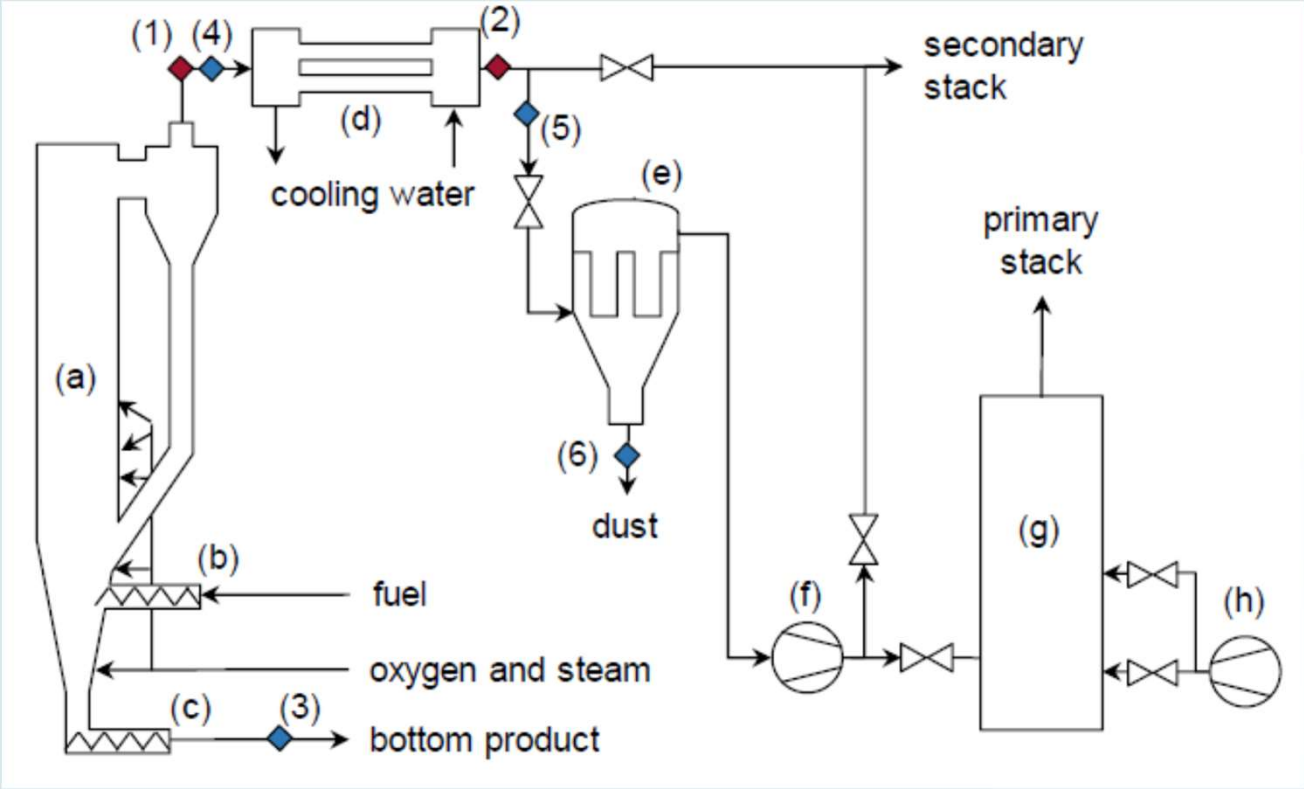
Waste to Chemicals Innovation Centre

R&D facility at TU Darmstadt (Energy Systems and Technology)

Key operating parameters

- Thermal Input: 500 kWth
- Gasification temperatures
  - Fluidized bed: 700 - 900 C
  - Free board: 800 - 1200 C
- Gasifier dimensions:
  - Height: 12 m
  - Diameter: 1 m
- Designed for long term tests of diff. feedstock
- Definition of key design and operational parameters
- Further process enhancement

HTW: Pilot Plant at TU-Darmstadt



(a) gasifier;
(b) screw conveyer;
(c) bottom product discharge;
(d) raw gas cooler;
(e) hot gas filter;
(f) syngas ventilator;
(g) thermal post combustor;
(h) fresh air ventilator;
(1) online moisture measurement;
(2) online gas analysis;
(3) bed inventory;
(4) tar measurement;
(5) gas sample bags;
(6) dust

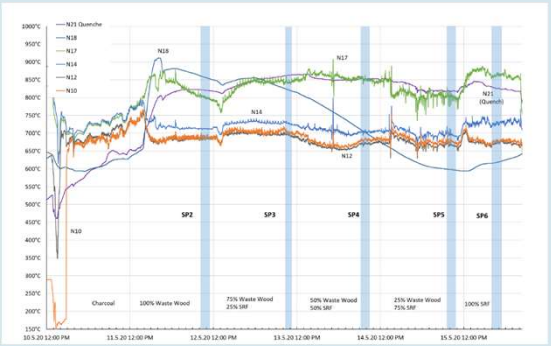
Cooperation with TU Darmstadt:
Continued long-term Feedstock Testing

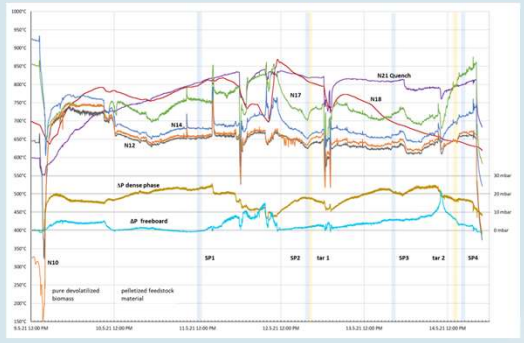
April 27th, 2020
- 100% FW pellets
- 100% RDF pellets
- Mixing

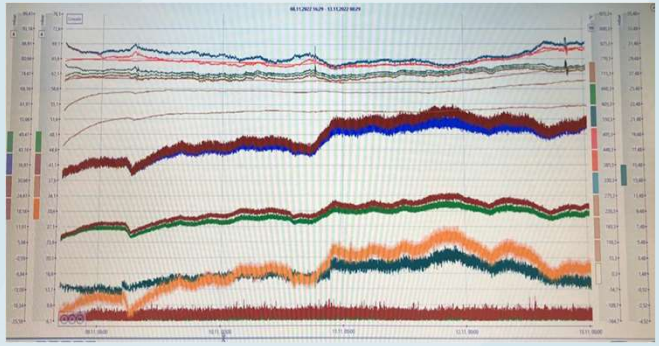
May 8th , 2021
- PFM: 75% RDF – 25% WW

Nov. 2022
- 100% WW pellets
- 75% WW pellets + 25% RDF pellets

June 2023
- Planned test for:
  - 75% WW pellets
  - 25% RDF pellets
  - Mixing



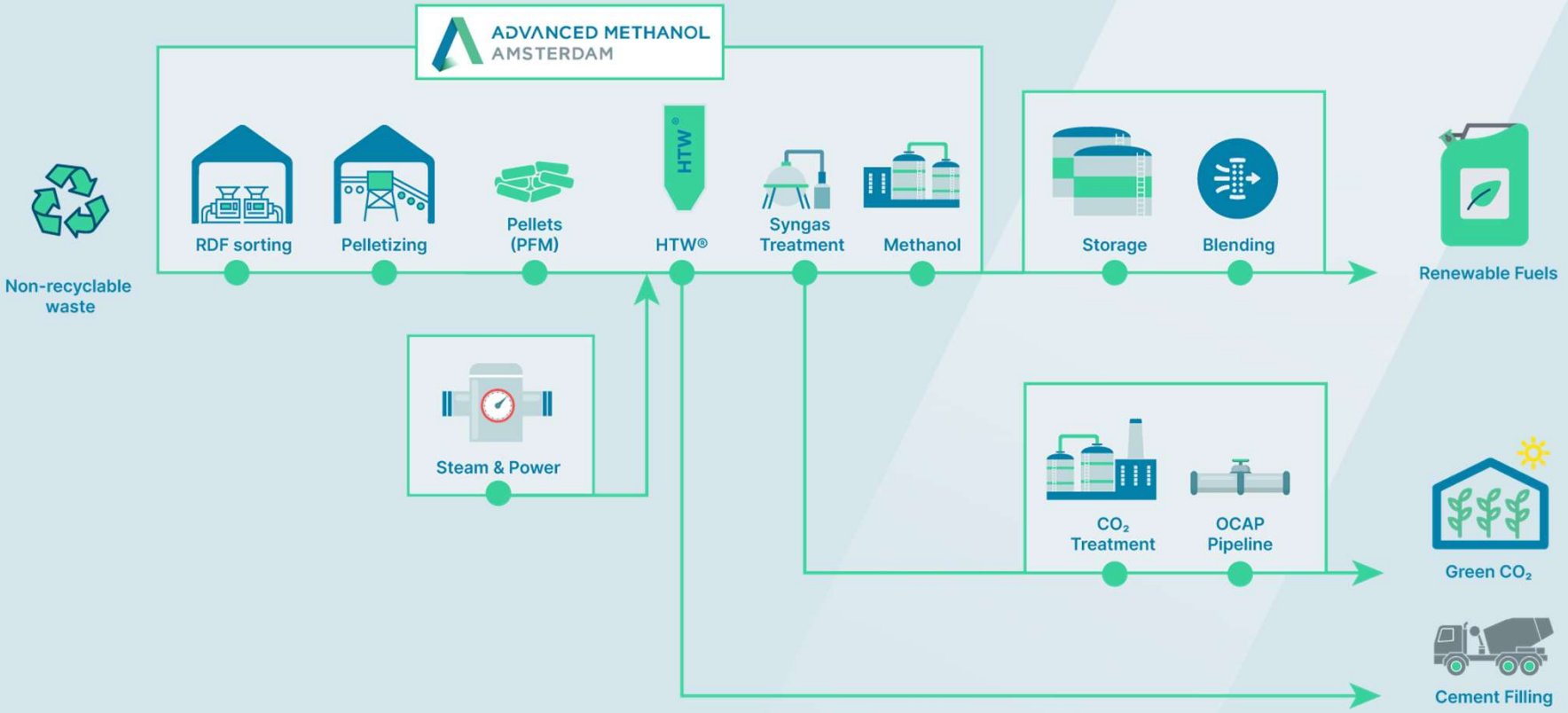




2 main targets:
- To test new RDF pellets
- To test new feedstocks:
  Peanut shell pellets
  Sunflower husk pellets

Flagship Facility “Advanced Methanol Amsterdam (AMA)”

HTW™-to-BioMethanol Plant: Process Flow Diagram



#	Interface
1	**PARO** supplying waste wood and RDF
2	**Pelletizing Company** with conveying line to Gasifier
3	**Methanol**
4	**Blended fuel** – RED II requirement for bp
5	**Dust and bottom product** to cement industry
6	Linde/OCAP to export **CO2**
7	**Power** supply

Flagship Facility “Advanced Methanol Amsterdam (AMA)”

HTW™-to-BioMethanol Plant (15 bar, 530 tpd) – HTW™ Section

Feed:	22 t/h
Operating pressure:	15 bar
Raw Syngas production:	41,000 Nm3/h
Cold gas efficiency:	> 80 %
Carbon conversion:	95 %
In operation:	2025
Bio-Methanol Production:	260 mtpd
Type of feedstock to be used:	RDF pellets and Waste Wood pellets

Advanced Methanol Amsterdam Plant

Twin facilities

Amsterdam

ADVANCED METHANOL

Rotterdam

Concluding Remarks

- GIDARA's goal is to meet the demand for cleaner fuels
  - address the waste challenges,
  - reduce global carbon emissions and
  - contribute to more circular economy;
- GIDARA has acquired the commercially proven HTW™ gasification technology;
- Ongoing R&D program focused on:
  - long-term pilot tests of different feedstock to define key-operating gasification parameters and to demonstrate the flexibility of HTW® for a variety of feedstock
  - further improvement of in-house numerical tools developed for modeling and design of HTW ® gasification process
- GIDARA Energy is currently building its commercial flagship facilities "Advanced Methanol Amsterdam (AMA)" and Advanced Methanol Rotterdam (AMR)" that convert RDF and Waste Wood into advanced Bio-Methanol.

Thank you!

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