Enefit Development Activities in Shale Oil Production

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Enefit in Brief

Eesti Energia is the largest oil shale to energy company in the world.

Oil Shale Mining	Oil Shale Power Generation	Shale Oil Production	International Development
• Over 100 years operations, more than 1 bn tons of oil shale mined to date • Reserves of more than 1 bn tons • Annual production ca. 15-17 M tons • 3 operating mines: 1 surface, 2 underground • 3 000 mining employees • Experienced in remediation 12 000 hectares restored	• Provides 91% of Estonia's electricity, more than 600 TWh produced to date • 2380 MW of oil shale fired capacity world largest oil shale power plants • Allows significant electricity exports to Baltic region and Finland • Ensures security of supply • Approx 881 employees	• 50 years of surface retorting experience • More than 200 M bbl oil produced to date • 30 years of commercial operation of the Enefit140 units • 2012 annual production more than 1M bbl • New generation Enefit280 is in operation in Estonia	• Based on Enefit280 shale oil production technology • USA: 50,000 bbl/d oil, resource is owned/leased • Jordan: 38,000 bbl/d shale oil production, 474 MW power production, resource is via concession • Enefit280 technology is available for licensing

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What is oil shale?

- **Oil shale is not shale gas or tight oil (shale oil)**

- **Oil shale** is an organic-rich fine-grained sedimentary rock containing kerogen (a solid mixture of organic chemical compounds) from which liquid hydrocarbons called shale oil (not to be confused with tight oil) can be produced. (*Wikipedia*)

Properties

- Heating value: 8,4 MJ/kg
- Density: 1000 kg/m^3
- Oil yield in Enefit140: 15,1% d.b.

Proximate Analysis

- Mineral content: 42 - 50%
- Moisture: 9 - 12%
- Organic content: 25 - 30%

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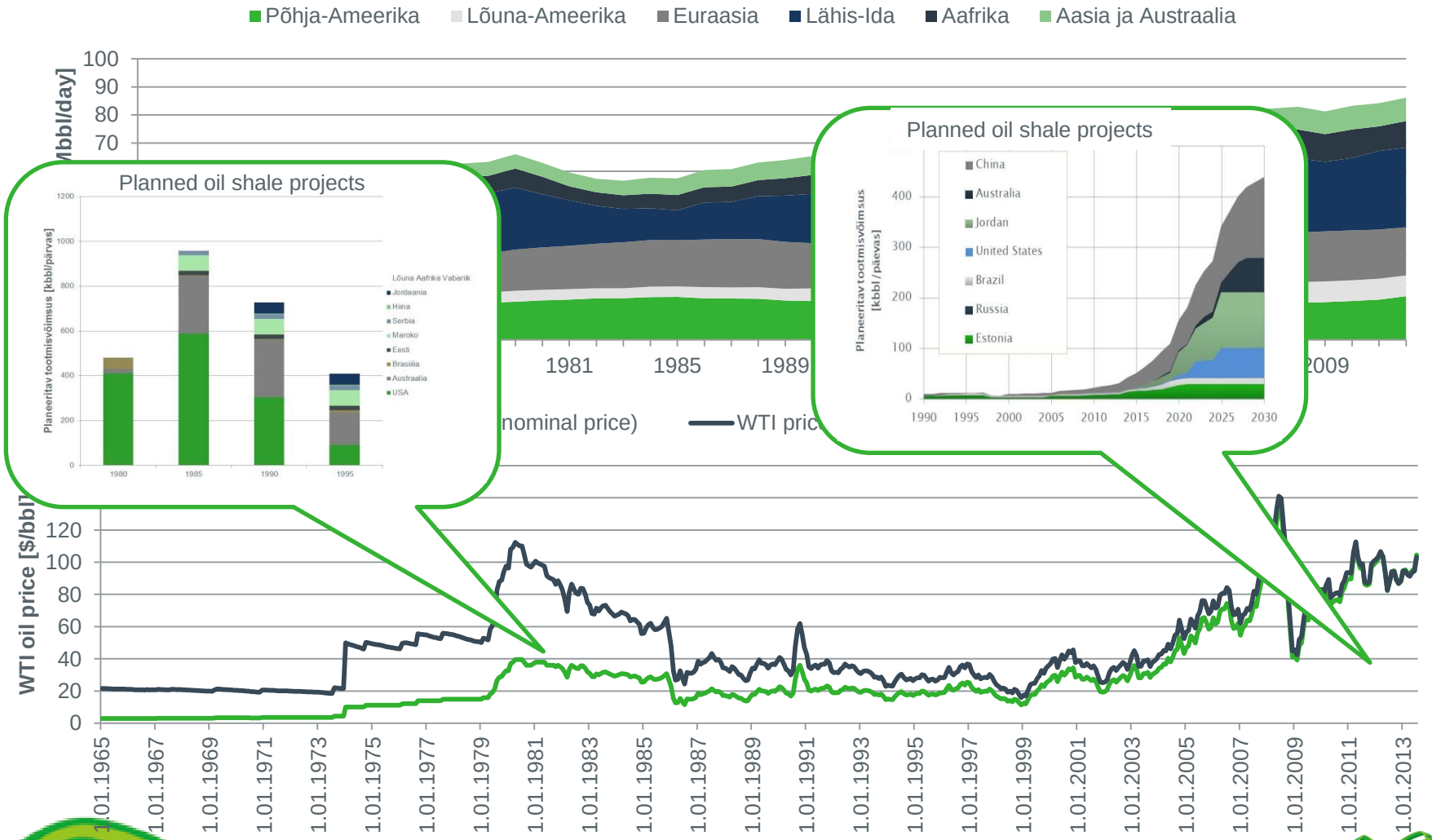
Shale oil production is only dependent on oil prices



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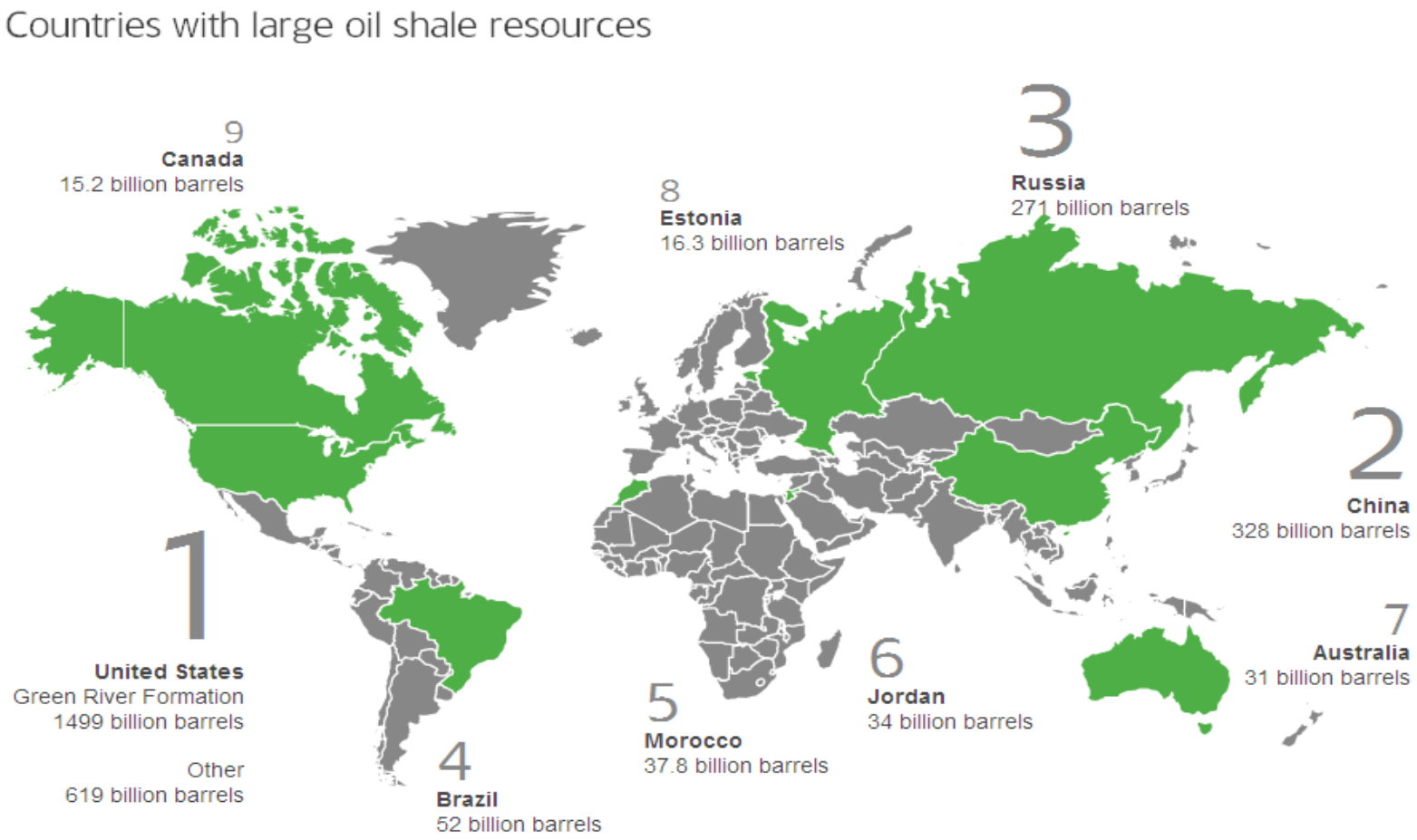
World Oil Shale Ressource



- **World Oil Shale ressource is estimated to exceed 2,800 billion barrels of oil equivalent**
- **For last 10 years oil price has been high enough to start large scale utilisation of oil shale**
- **Breakthrough in oil shale utilisation has not happened due to low oil price and absence of efficient and environemntally friendly shale oil production technology.**

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All oil shales are different –

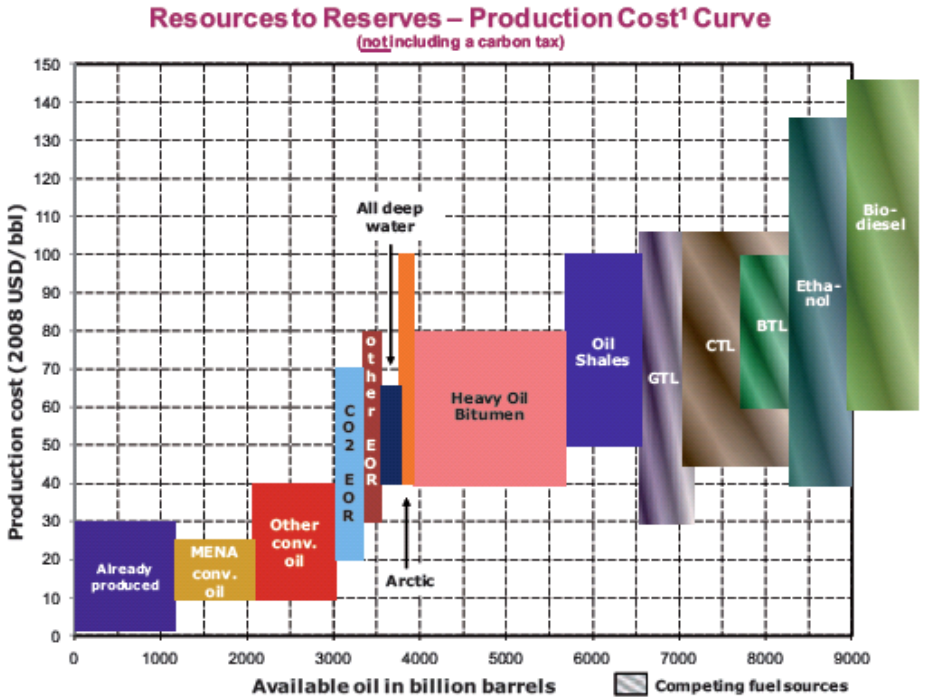
different moisture contents, oil yields and calorific values

	Kukersite (EST)	Green River (USA)	Attarat (JOR)
			
Moisture	12%	1%	17%
Ash	52.2%	63,9%	62,6%
Gross calorific value	8.3 MJ/kg	5.0 MJ/kg	5.7 MJ/kg
FA oil content:	17.4%	10.5%	8.2%
Elemental composition:			
Total carbon	25.4%	17.6%	18.6%
Carbonate carbon	6.7%	6.4%	5.9%
Total hydrogen	2.3%	1.6%	1.6%
Total sulphur	0,4%	0.5%	2.9%
Total nitrogen	0.1%	0.5%	0.3%
Mineral matter:			
CaO	51.8%	32.6%	49.8%
SiO_2	22.8%	38.5%	31.8%
MgO	6.5%	9.6%	1.1%
Al_2O_3	5.6%	7.4%	3.0%
Fe_2O_3	4.2%	3.2%	1.2%

Economics of oil production alternatives

- Alternative oil production methods cannot compete with conventional crude oil pumping in Saudi-Arabia and Russia
- Crude oil pumping from deep waters (e.g. Brazil) or polar areas (e.g. Alaska) have production costs around 40-80 $/bbl
- Production of synthetic crude oil from oil sands and heavy oil has production cost around 40-100 $/bbl
- Oil production from oil shale becomes profitable at oil prices starting from 50 $/bbl
- Production of oil from gas, coal or biomass requires already higher prices (50-100 $/bbl)

At current oil prices almost all alternatives are competitive.



Source: An updated version of the IEA's 2005 publication *Resources to Reserves: Oil and Gas Technologies for the Energy Markets of the Future* to be published later this year.
¹*Production cost is defined as the break-even point and does not include an assumed return on investment*

Source: IEA Medium-Term Oil & Gas Markets 2011

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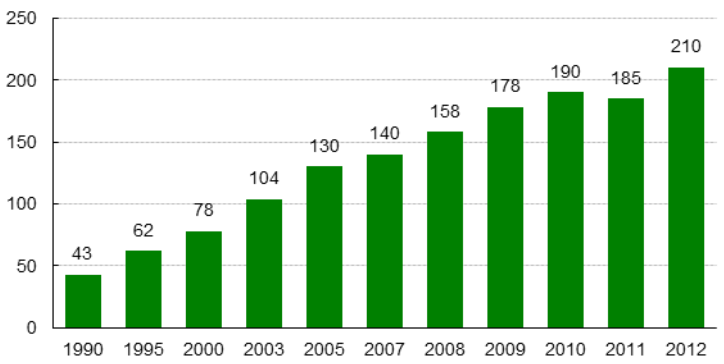
Narva Shale Oil Plant

Enefit possesses a unique process from oil shale mining through to shale oil production

- **Shale oil and retort gas – Narva Oil Plant**
  - Commissioned in 1980
  - **80% of the equipment has been replaced and improved by plant engineers since its commissioning**
  - Two unique Enefit140 trains (each train capacity is 140 t/h of oil shale)
  - The maximum output is 220 000 t of oil per year
  - Retort gas production: 60 mil. Nm^3/year (used for power generation)
  - Established by EE in 2007 as a separate legal entity
  - 315 employees (85 employed for Enefit280)
  - FY2011 total revenue – 73 mil EUR
  - FY2010 net profit – 33,4 mil EUR
  - Increased shale oil output upon new (280 t/h of oil shale) advanced plant construction completion in 2012

Narva Oil Plant – 2 Enefit140 trains

Enefit Shale Oil Output (th t)



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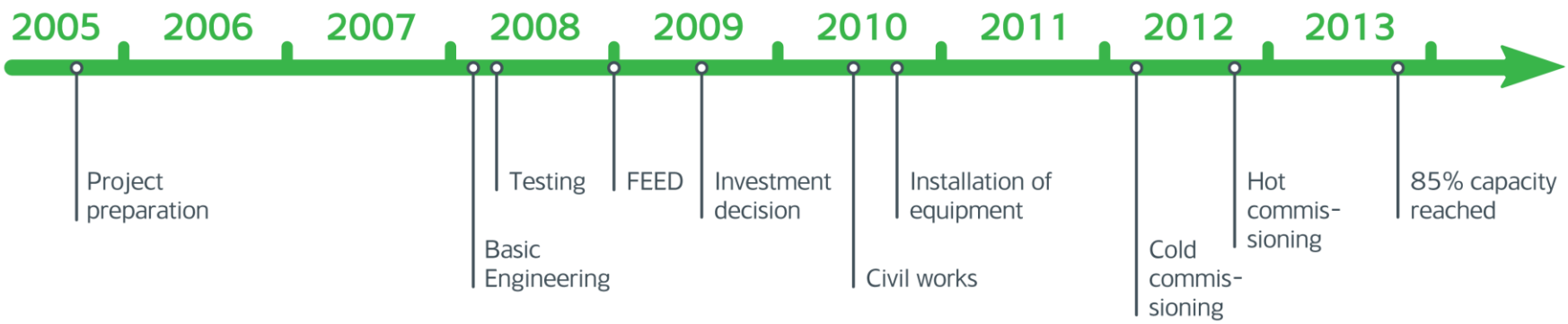
Enefit’s shale oil production today

Timeline of Enefit280 Project



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Main characteristics of Enefit280

Enefit280 is combined oil, power and gas generation plant:

- Plant capacity: 280 tpsh
- Annual oil shale consumption: 2,3 million tonnes
- Annual shale oil production: 290 000 tonnes (1.9 mil. bbl)
- Annual retort gas production: 75 mil. m^3
- Annual power production: 280 GWh
- Designed lifetime of the plant: 30 years
- Construction time: 26 months

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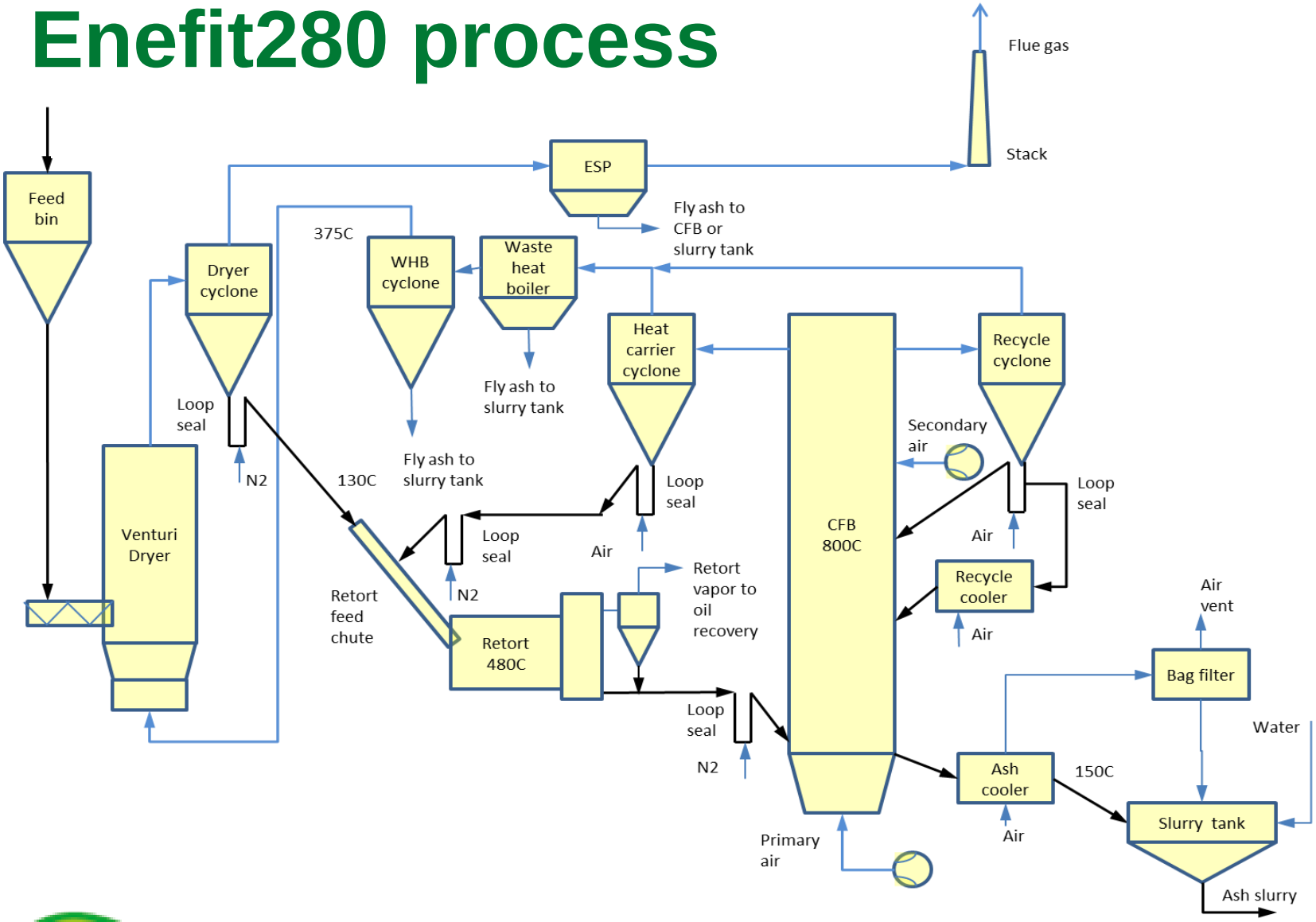
Enefit280 process



Production of motor fuels from shale oil

- In 1980's syncrude was produced from shale oil in US
- Parachute Creek (CO) plant proved that it is technically possible to produce motor fuels from shale oil.
- Motor fuels that meet today's specifications have been never produced from Estonian oil shale.
- Comparison of different shale oil properties:

		Utah shale oil	Attarat shale oil	Estonian shale oil
API gravity	° API	25	18,2	21,3
Pour Point	° F	**64**	-6	-76
Chemical composition of shale oil				
Carbon content	wt.-%	83,41	79,85	83,4
Hydrogen content	wt.-%	11,23	9,7	10,4
Nitrogen	wt.-%	**1,74**	0,5	0,19
Sulfur	wt.-%	0,5	**9,04**	0,75
Oxygen	wt.-%	1,19	1	**5,23**

- Every shale oil is different and upgrading concept should take these differences into account.

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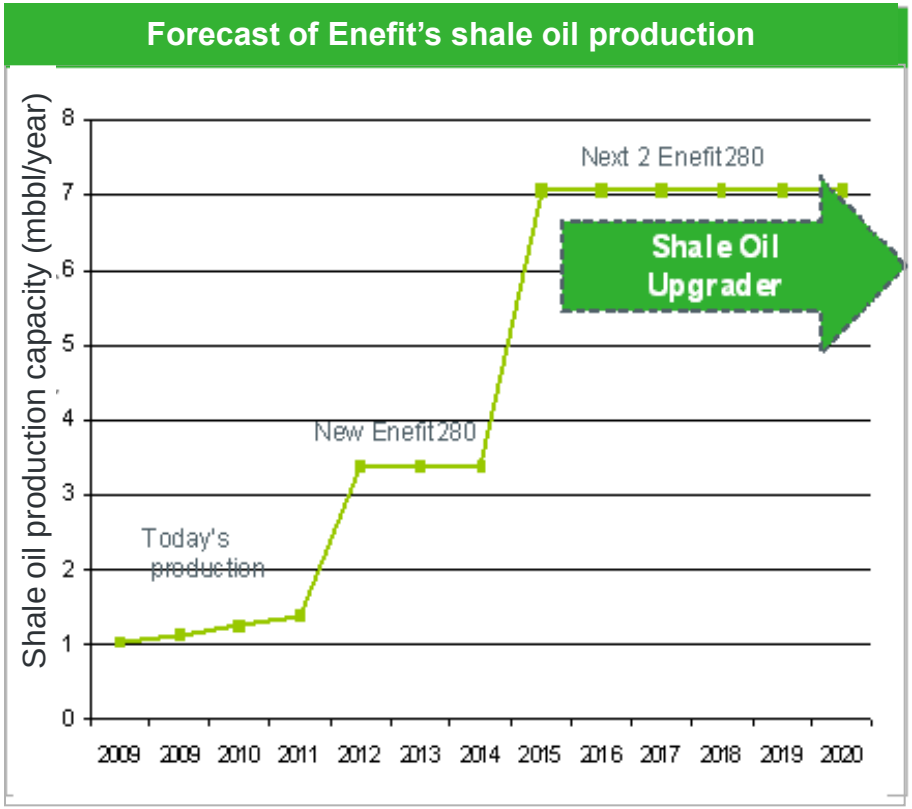
Shale oil upgrader in Estonia

- Enefit plans to expand its shale oil production capacity to 22,000 BPSD
- Enefit has successfully tested hydroprocessing of Estonian shale oil in 3 different laboratories
- Enefit completed the upgrader pre-FEED study in 2012
- Enefit performed the FEED study in 2013
- Enefit shale oil upgrader project was put on hold in 2013 due to increased CAPEX estimate.



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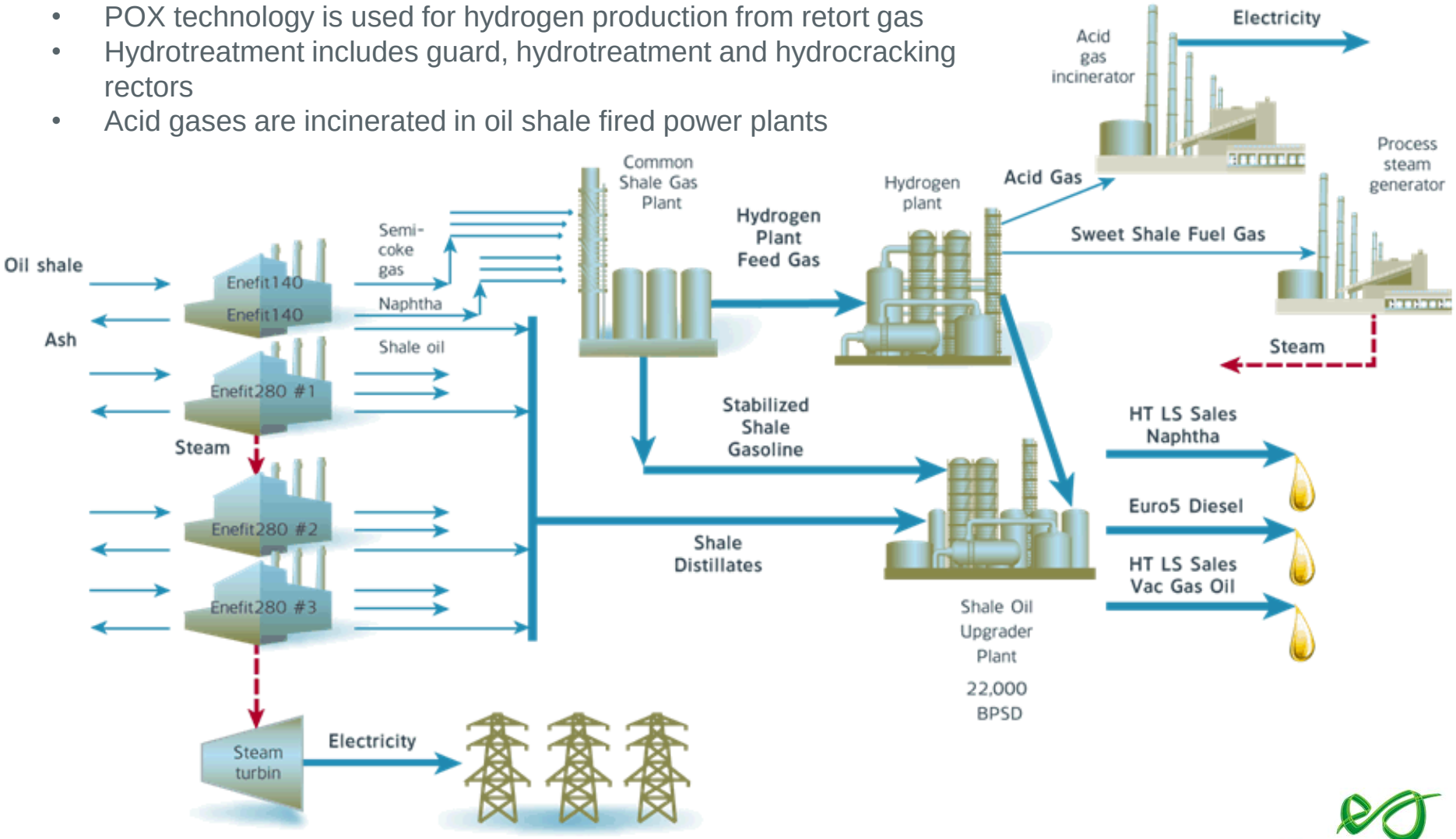
Oil Shale Industry Scheme

Upgrader concept:

- POX technology is used for hydrogen production from retort gas
- Hydrotreatment includes guard, hydrotreatment and hydrocracking rectors
- Acid gases are incinerated in oil shale fired power plants



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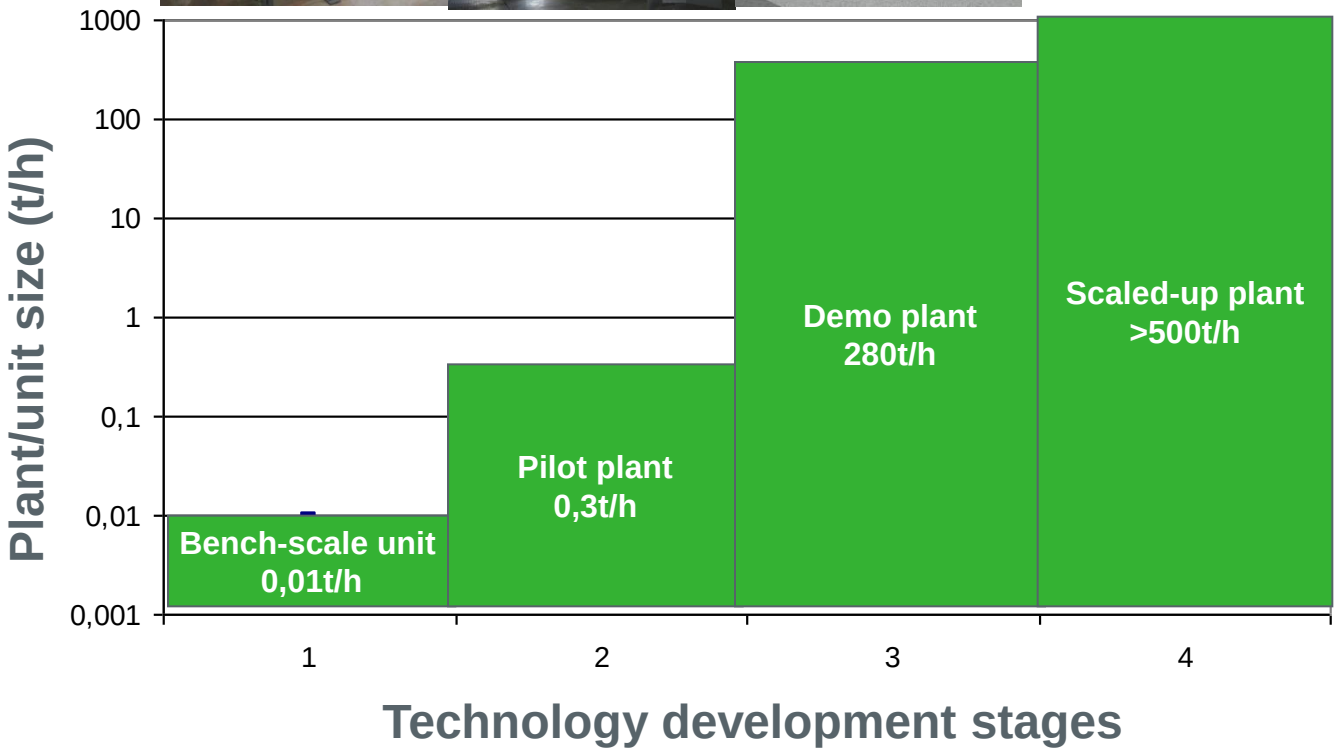
Enefit technology development stages



- All technology development stages have to be passed with each oil shale:
  - All oil shales are different
  - Minimisation of risks
- All stages have been carried out with Estonian oil shale, but Estonian plant cannot be copied to anywhere else;
- EE together with Outotec has created capability to carry out all development stages;
- Shale oil production process has to be developed from scratch for each oil shale taking into account:
  - Oil shale properties
  - Local conditions
  - Product market conditions

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Enefit Bench-Scale Unit

General

- Designed by Enefit and Outotec
- Located in Outotec's R&D Center in Frankfurt
- Unit is owned and operated by Enefit Outotec Technology
- Commissioned in 2010
- Aim is to test different different oil shales and determine oil and gas yields and compositions
- Tests have been performed with oil shale from Estonia, Jordan, China and USA

Main Characteristics

• Oil shale feed (<6mm)	4 – 12 kg/h
• Ash to pre-heater	10 – 25 kg/h
• Ash temperature in pre-heater	700 – 800 ºC
• Pyrolysis temperature	440 – 530 ºC
• Shale oil production	up to 2 l/h

- Heat carrier is prepared at OT's 700mm pilot CFB

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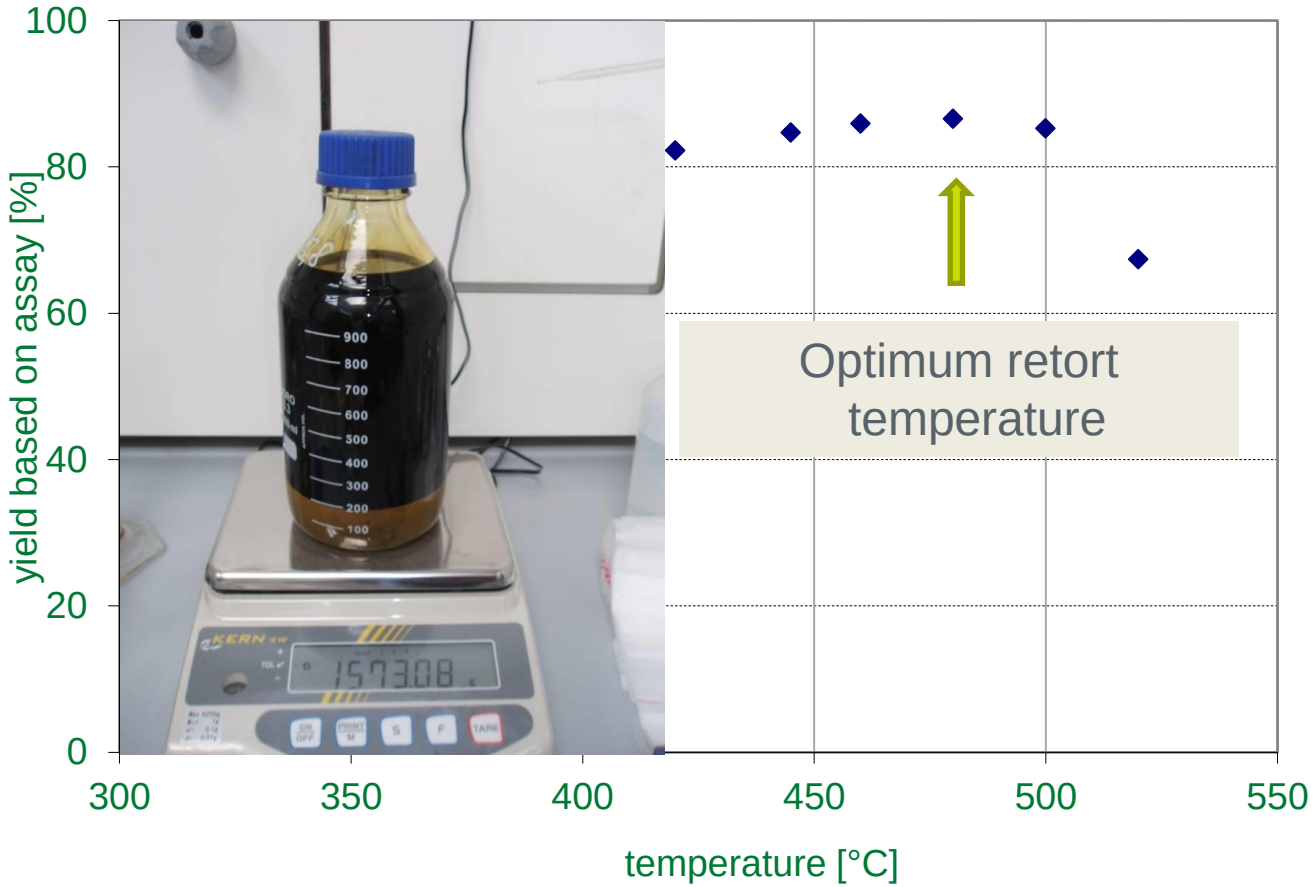
Tests with Jordanian oil shale



Properties of Jordanian oil shale:

–	Dust content	60 ppm
–	Density @15 ºC	16 APIº/ 960 kg/m³
–	Viscosity @40 ºC	3.5 mm²/s
–	N+O content	~ 2 %
–	Sulfur content	8 – 10 %

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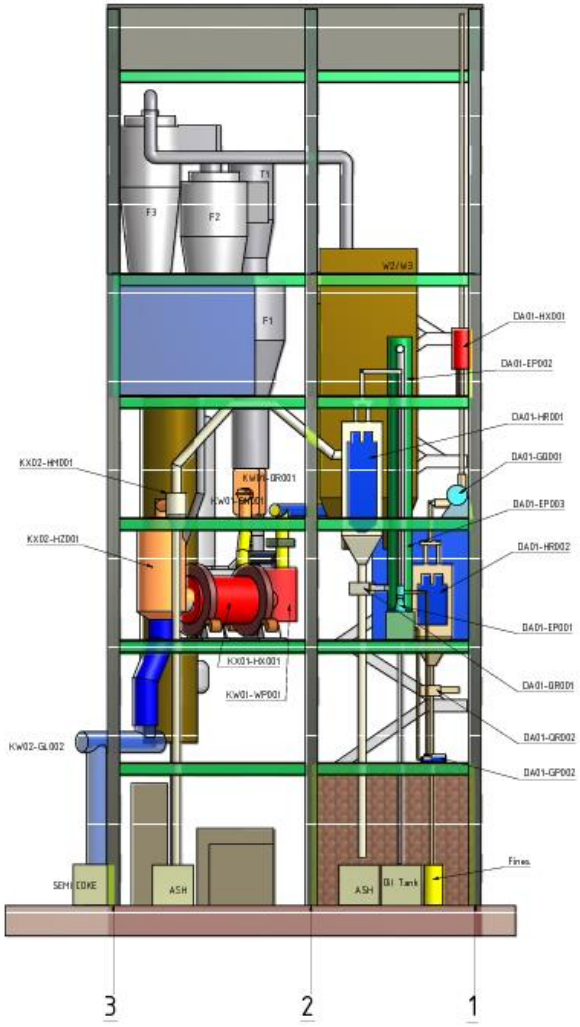
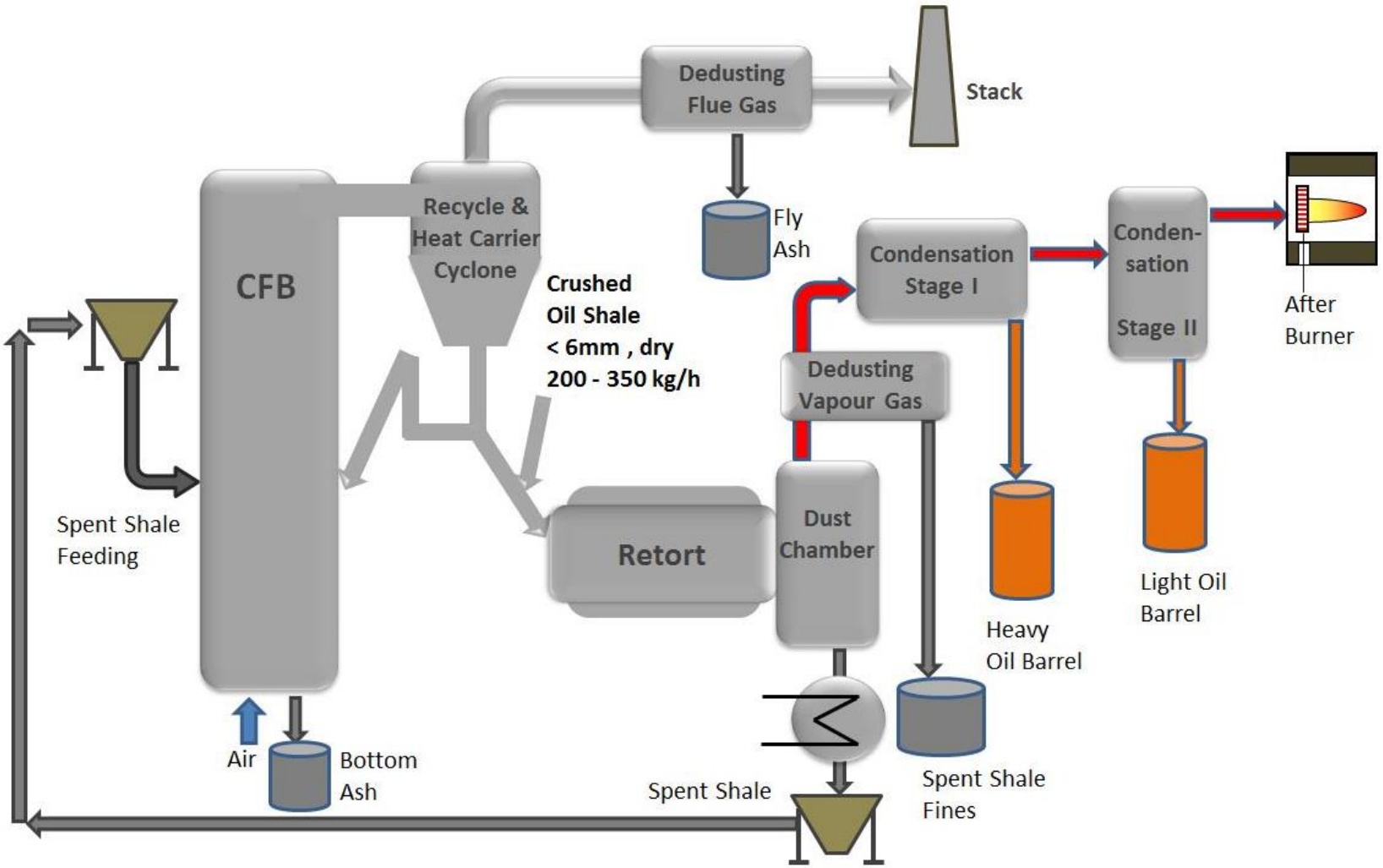
Enefit Pilot Plant

- Location: Frankfurt R&D Center, Germany
- Operated by Enefit & Outotec
- First oil production May 2013
- Final hot commissioning run with Estonian shale in June 2013
- Needed for technology development and adaptation for „unknown“ oil shales
  - Reduce risks
  - Determine optimum retorting conditions (temperature, retention time etc.)
  - Distribution and properties of products, by-products and internal streams under optimum process conditions
  - Information are gained by test work on different scales



Enefit Pilot Plant – Flow Diagram



Test campaign with Utah shale

- Test campaign Sept 9-16, 2013
- Two grades tested at stable conditions at 250 kg/h oil shale feed rate
- Oil, ash, spent shale, retort gas samples taken at intervalls of 1 – 4h
- Oil, oil shale, gas and solid samples being analyzed internally and externally by client contracted (North American) laboratories
- First evaluations on solid streams carried out
- Final evaluation including different elemental balances to be finalized after inspection and receiving external laboratory results.

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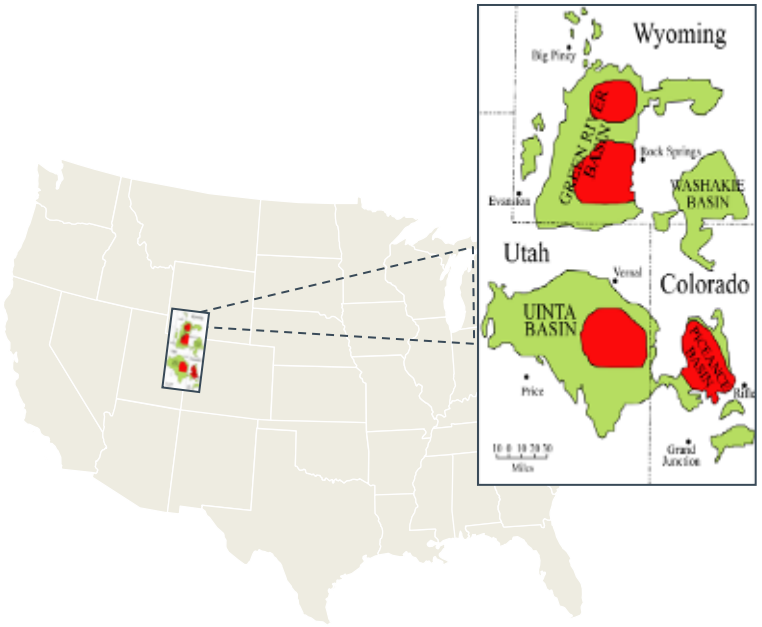
Enefit development project in Utah (USA)

Enefit Amercian Oil (EAO) ownership: 100% Enefit

Project schedule:
-25 000 bbl/day of shale oil in 2020
-50 000 bbl/day total capacity of Enefit shale oil plants in 2024

Resource in USA, Utah



- Oil in Utah, approximately 300 km east of Salt Lake City
- Total resource of EAO is 2.6 billion bbl of oil
- EAO Ressource: private property, leases and options

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Enefit development projects in Jordan

Jordan Oil Shale Energy (JOSE) ownership: 65% Enefit, 30% YTL, 5% Near East Group

Project schedule:

- *474 MW oil shale fired power station in 2016*
- *19 000 bbl/day of shale oil in 2020*
- *38 000 bbl/day total capacity of Enefit shale oil plants in 2024*

Concession Area in Jordan

- Oil Approximately 110 km south of Amman
- Total resource of JOSE is 1.9 billion bbl of oil
- JOSE Resource: Concession Agreement

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Thank you!

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