



Verification program with Vattenfall,
4300 tons at Reuter West, Berlin



arbaflame®

The Original Steam Explosion Pellets



Thunder Bay GS – world first full
conversion to Advanced Wood Pellets



Handled as coal thru the value chain

*Presentation
Cenbio
september 2015*

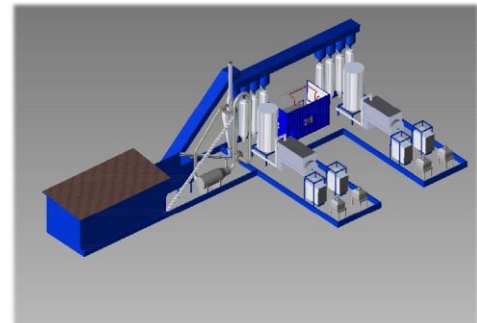
Rune Brusletto



Grasmo Steam Explosion Pellet Plant
- built in 2003

Arbapellets[®] - the original steam explosion pellets

- Production since 2003 in Grasmo Plant, Norway
 - Accumulated production 120 000 tons
 - Capacity ~ 25 000 tons/year
 - Patented Production Process
 - Domestic heating market
 - Reduction material for smelters
 - Since 2010 – focus on coal replacement
 - Verification program
 - Test volumes for coal plants
 - Fine-tuning of production process and product properties
 - Test of different raw material
- ➔ Long, unique experience from producing and testing
- ➔ Industrial scale-up by additional units



Arbapellets - Advanced Wood Pellet (AWP) or Black Pellets – key advantages

Arbapellets vs. White Pellets

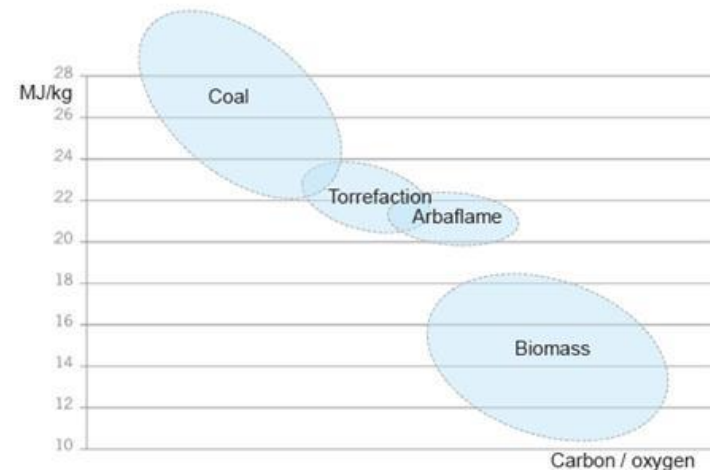
- Water resistant
- “Dust free” – lower dust explosion risk
- 40 % lower volume - same energy content
- Lower handling, storage and transport cost
- Outstanding mechanical properties



Water resistance represents a key advantage

Arbapellets vs. Coal

- Energy value and other properties close to coal
- Transport, storage, handling, milling and combustion with same equipment
- Coal replacement up to 100 % with minor modification (white pellets up to 5 %)
- Reduction of CO₂ emissions by 100 %







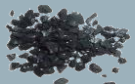
Arbapellets favorably positioned compared with alternative technologies

Fuel comparison



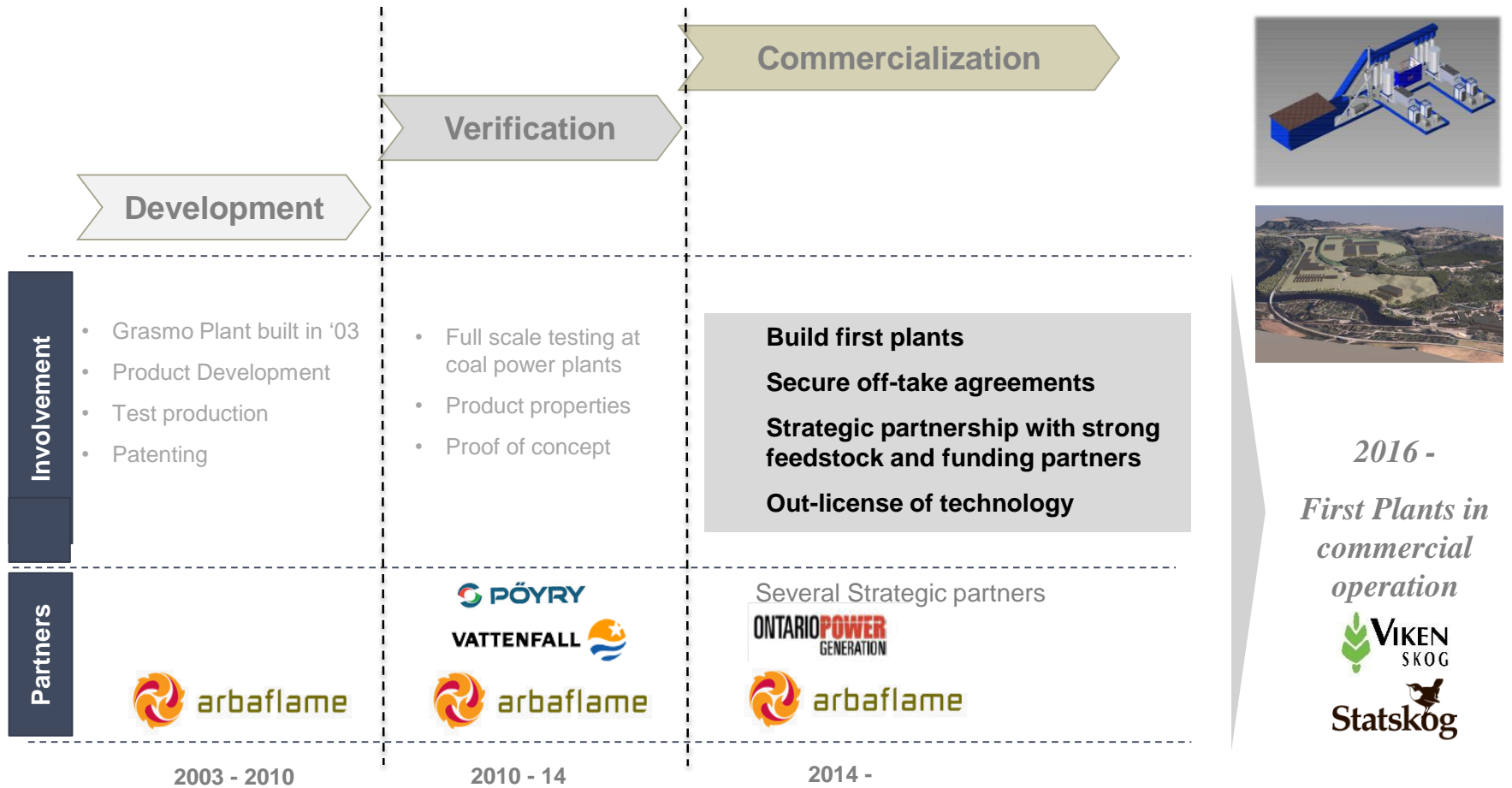
----- Properties -----

----- Technology status -----

	Wood chips	Wood pellets	Arbapellets	Torrefied pellets	Hard Coal
					
Heating Value	10-12 GJ/ton	17 GJ/ton	19,5 - 21 GJ/ton	21-22 GJ/ton	25 GJ/ton
Bulk density	300 kg/m ³	650 kg/m ³	750 kg/m ³	750 kg/m ³	850 kg/m ³
Energy density	3 GJ/m ³	11 GJ/m ³	14,5-15,5 GJ/m ³	17 GJ/m ³	21 GJ/m ³
Water resistant		Poor	Very good	Good ?	
Durability	n.a	Good	Very good	Good ?	Very good
Binder		No	No	Binder needed	
Mass loss	n.a		10 - 15 %	> 35 %	
Co-firing rate	3-5%	5-8%	> 100% proven	?	n.a
Millability		Poor	Good	Good ?	
Dust % delivered		High ~3-7 %	Low < 1%	> 5 -10% ?	Very good
Product Approval by Utility Testing			Yes	No	
Technical Dvlp. Status operation		Mature (20 years)	Demo Plant (> 8 years)	Pilot/demo plants (1-2 years)	
			READY TO BUILD		

Source: Arbaflame

Arbaflame development



Handled as coal throughout the supply chain with only minor modification

Transport

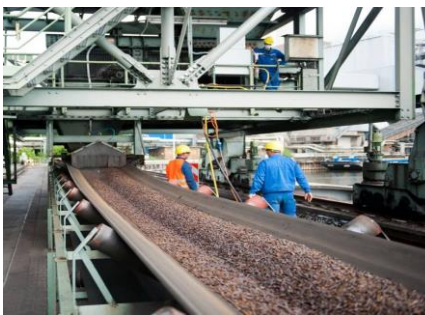
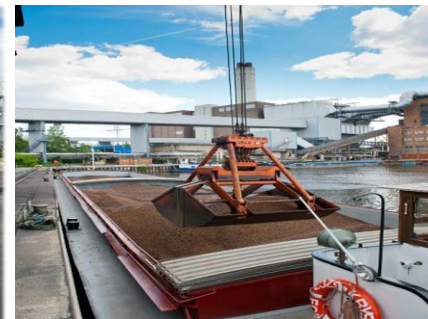
Handling

Outdoor Storage

Milling

Combustion

Vattenfall quote: *“Co-combustion lowest cost and capex option to reduce CO₂ in Europe”*



Full scale tests performed with Arba pellets at > 8 coal fired power stations



2010
Uppsala, Sweden
300 MW CHP



2010
Uskmouth, Wales
330 MW power station



2011
Reuter West, Berlin Germany
2 * 300 MW power station
Co-firing 20% to 50%



2012
Buggenum, Holland
Gassification 250 MW
Co-firing 50 and 70%



2012
Amager, Denmark
250 MW CHP



2013
Tilbury, UK
900 MW power station



2013 & 2014
Thunder Bay, Canada
312 MW power station
Dedicated 100 % capacity



2014
Hanasasari, Finland
200 MW power station



Ontario Power Generation, Canada

– converted two coal plants to 100% biomass

Atikokan GS

- 205 MWe – White Pellets
- Project duration
 - 18 months (9 month outage)
- Conversion Capex - Major
 - \$ 170 M (€ 600/KW)
 - New fuel receiving, storage silos
 - New burners and modification of mills
- Supplier – peaking plant
 - Two local suppliers

Thunder Bay GS Unit 3

- 150 MWe – Advanced Biomass
- Project duration
 - 7 months (2 month outage)
- Conversion Capex - Minor
 - \$ 5 M (€ 25/KW)
 - Outdoor fuel storage
 - Minor changes (safety and dust suppression)
- Supplier – peaking plant
 - **Arbaflame**

ONTARIOPOWER
GENERATION



Arbaflame - supplier to the world's first conversion to advanced wood pellets

Thunder Bay Plant operating on Arbapellets



Arbapellets in winter storage



Unloading at Thunder Bay Port



World's first commercial contract with advanced wood pellets (AWP) for **100% replacement of coal** based on:

2013

- May - Access to results from Vattenfall & Arbaflame verification program shared with Ontario Power Generation
- June - Delivery of 20 tons for external lab testing
- Sept - Delivery of 1200 tons for full-scale verification

2014

- July - Arbaflame selected as supplier for first commercial volume
- Sept - First delivery arrived Thunder Bay for storage

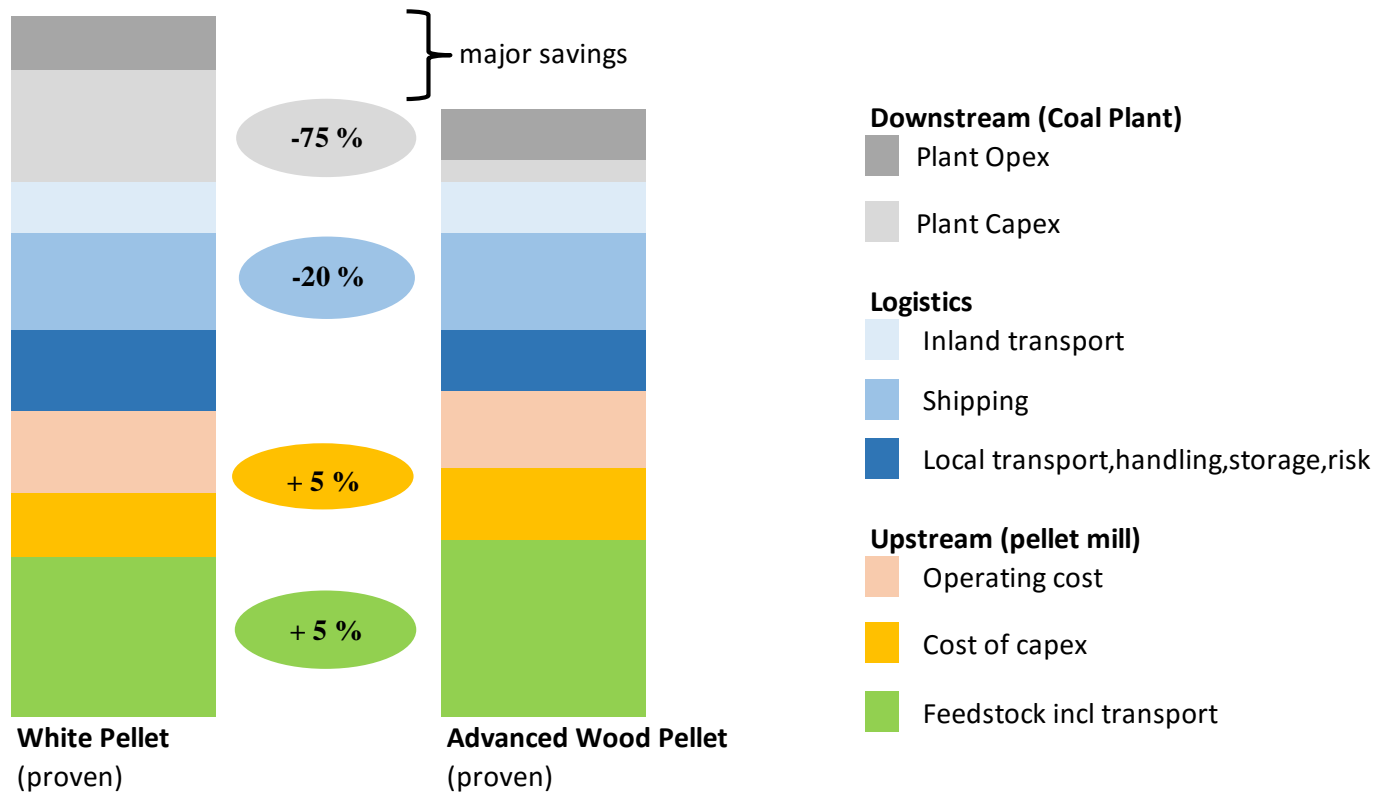
2015

- Jan – Commercial operation

Upgrade biomass to AWP to achieve high co-firing rates and reduced cost

Fuel cost comparasion White and Advanced Wood Pellets

Eur/MWh fuel (indicative)



Source : Vattenfall & own analysis

■ Arbapellets

- ✓ Delivery separately
- ✓ Blending in line before milling from separate hoppers
- ✓ Blending after separate milling into combustion chamber

■ Arbaccoal

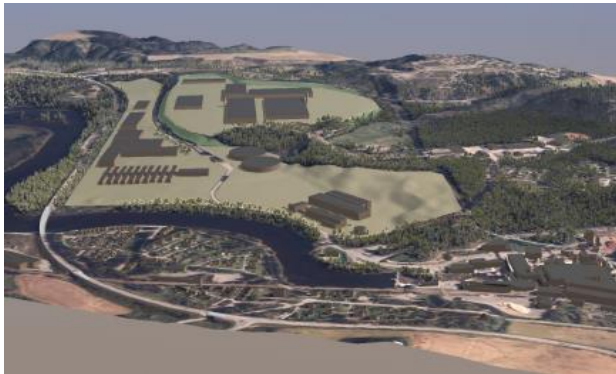
- ✓ Blended before delivery (one fuel and with outdoor storage)



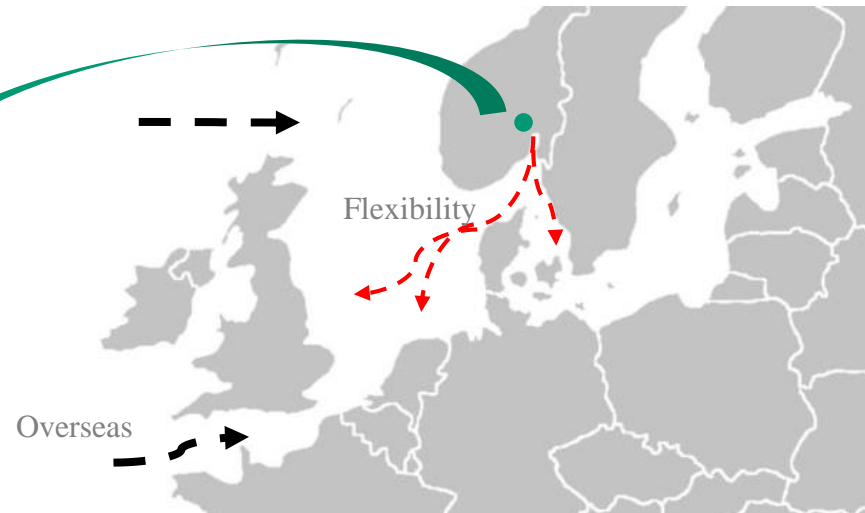
ArbaFollum Plant, Hønefoss Norway

Brownfield plant with biomass infrastructure

- Production capacity of 200 000 tons/year
- at Follum former Norske Skog paper mill site
- Stable feedstock supply from certified forest
- Final Investment Decision in 2Q 2015



Short distance to European utilities



Partners

arbaflame

Arbaflame - technology provider


Viken Skog - site owner and feedstock supplier


✓ owned by > 10 000 forest owners


Statskog - Norwegian State forest company




- Short distance to port – 70 km
- Maritime distance 1-3 days
- Direct access to customers with small and large vessels
- ➔ «FOB-port same as CIF ARA»
- ➔ Buffer volume/Storage option

-
-  Full replacement of coal is now possible with only minor modifications

 -  Arbapellets has lower fuel cost than white pellets including modification cost

 -  Arbapellets is a solution for using existing coal power plants and grid for:
 - green base-load power
 - green flexible peaking (dispatchable) power

 -  Security of supply is coming
 - build co-owned plants
 - partnerships



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