Levulinic Acid

The platform for cost competitive low carbon footprint bio-based specialty chemicals and materials

Opportunity for local commoditized ligno-cellulosic feedstock

Powered by DSM technology

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Rusthoeve, Colijnsplaat, 9 March 2016

Summary

- Levulinic Acid (LA) and gamma valerolactone (GVL) are recognized as important bio-based platform molecules. The current market price is above 3 $/kg, serving specialty markets. The current production capacity, based on corn cobs, mainly in China, is about 5 kT/y.
- For serving commodities, the cost price of LA and GVL should significantly drop to, say, <1 $/kg. Then markets of 1000 kT/y and more for a wide variety of bulk *drop-ins* come in reach.
- *Drop-ins* can be *molecular* (e.g. adipic acid) or *functional* (e.g. gamma valerolactone replacing another solvent).
- For reaching this cost new biobased raw materials, better technology and smart scale-up are required.
- DSM owns the LA platform technology and can offer development and implementation of the LA platform.

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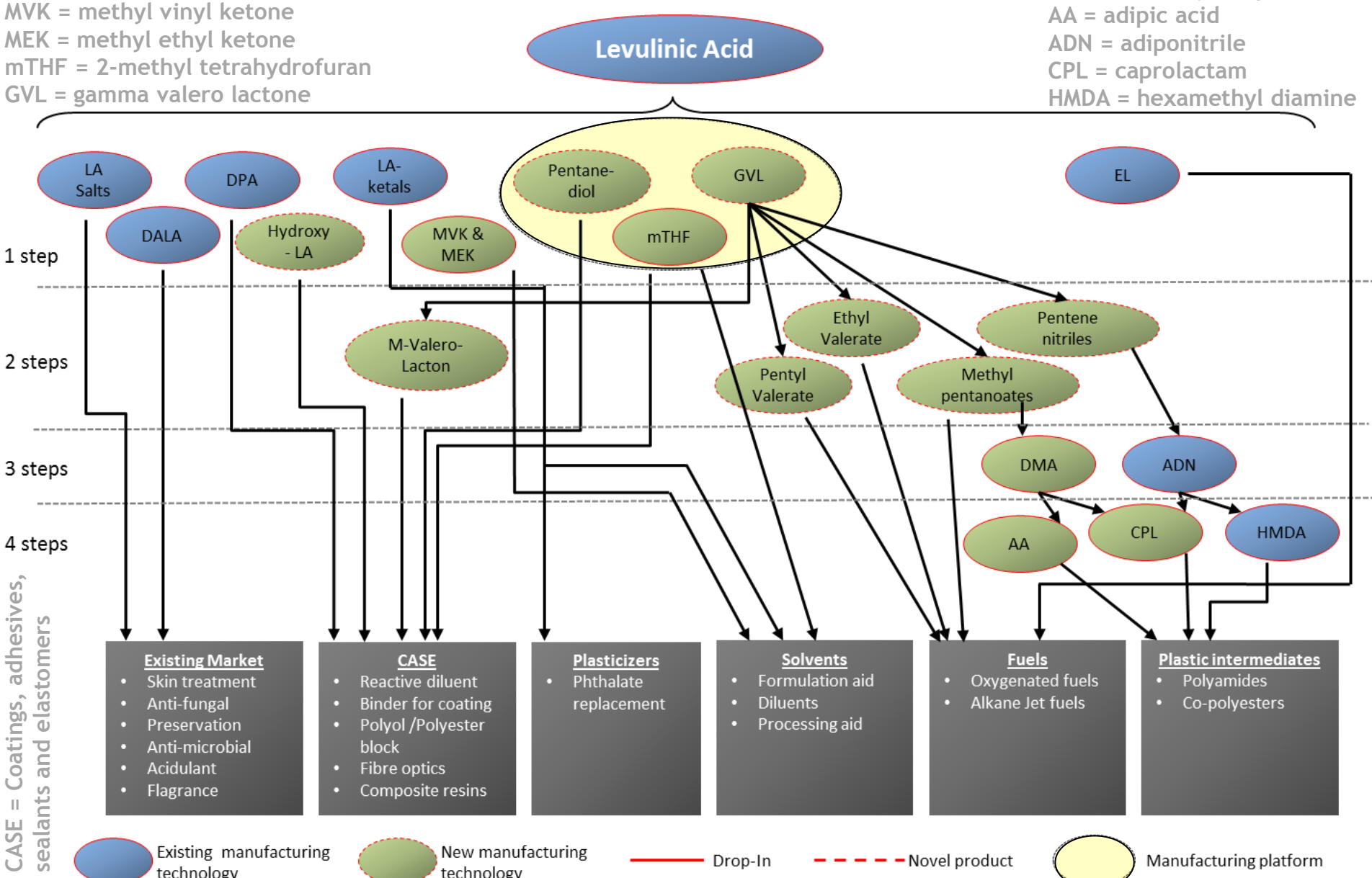
An attractive versatile platform

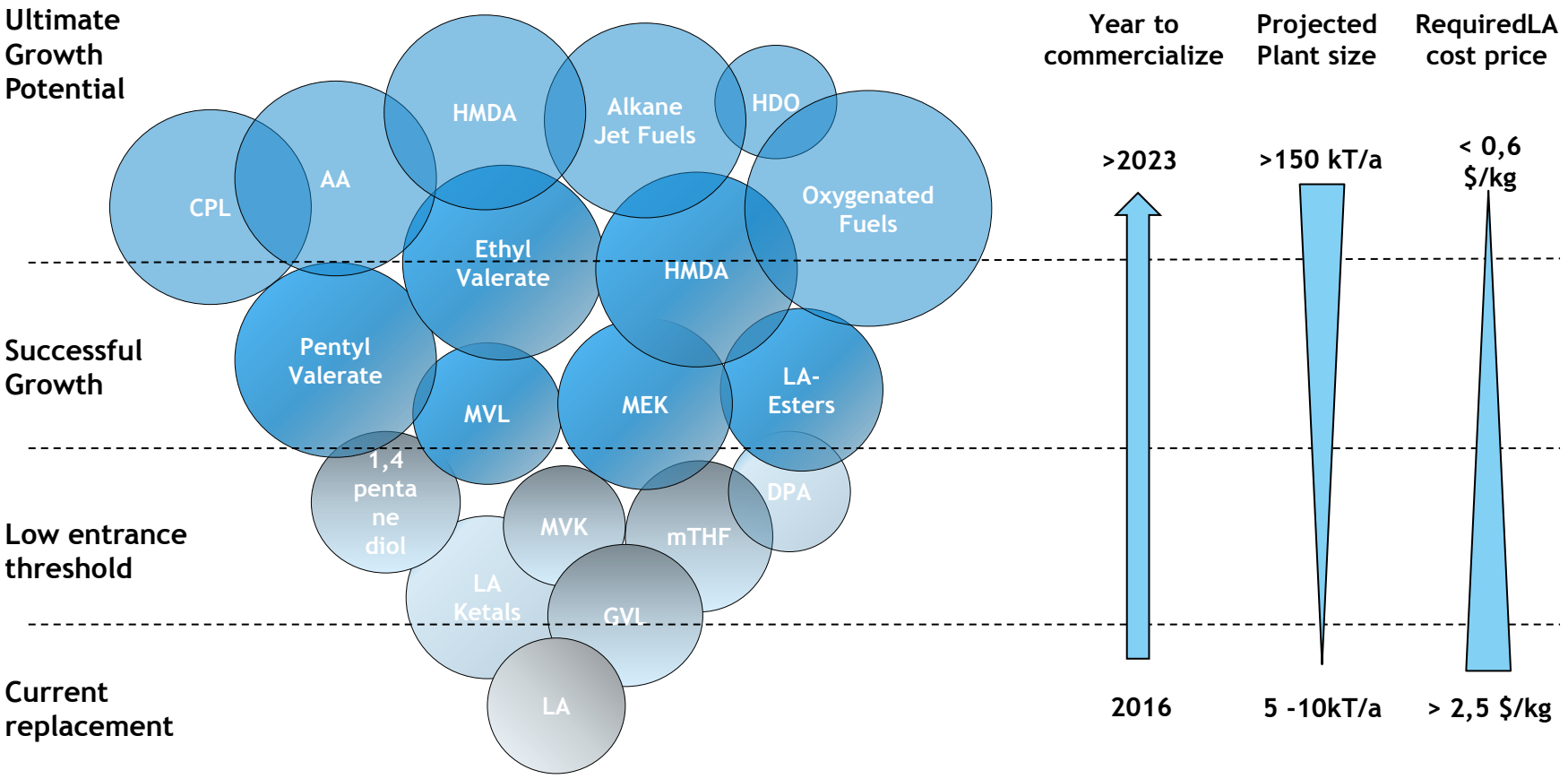
DALA = delta-amino levulinic acid
DPA = diphenolic acid
MVK = methyl vinyl ketone
MEK = methyl ethyl ketone
mTHF = 2-methyl tetrahydrofuran
GVL = gamma valero lactone

EL = ethyl levulinate
DMA = dimethyl adipate
AA = adipic acid
ADN = adiponitrile
CPL = caprolactam
HMDA = hexamethyl diamine



Market potential is huge

Levulinic acid cost price drives market adoption



HDO = hexanediol
DPA = diphenolic acid
MVK = methyl vinyl ketone
MEK = methyl ethyl ketone
mTHF = 2-methyl tetrahydrofuran

GVL = gamma valero lactone
HLA = hydroxy levulinic acid
AA = adipic acid
CPL = caprolactam
HMDA = hexamethyl diamine

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Potential markets for the emerging LA-platform

Huge opportunities for growing a very attractive business

Estimates in 2029	Market volume (kt/a)	Market value ($*bn*)
Current market	6	0,01
Plasticizers	12000	15
Coatings, adhesives, sealants & elastomers	9000	15
Solvents	26500	25
Polyamide intermediates	14000	25
Bio-fuels	1600000	1000

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Commercial Levulinic Acid Technology

Bio-based but not sustainable

- Corn cobs or bagasse → Furfural → Furfuryl alcohol (60 kT) → LA → GVL and other products (10 kT). Many small suppliers concentrated in China. Market is growing fast.
- Only C5 sugars (35% of dry weight of corn cobs and 25% of bagasse) are converted to furfural. Low efficiency. Lot of char formation.
- About 10 kg corn cobs / kg LA required
- Carbon footprint about 6-7 kg CO_2 / kg LA
- Estimated cost price 2.5$/kg

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DSM Levulinic Acid technology

Economically attractive, bio-based and zero carbon footprint

- LA feedstock: many C6 sugars containing feed stocks like ligno-cellulosic biomass or recycle wood can be used.
- C6 sugars in all feed stocks are converted with molar yield of 60% to LA and (bio-based) Formic Acid (FA). DSM tested glucose, softwood, hardwood, pulp and pulp containing process effluents, and several qualities of recycle wood.
- C5 sugars in woody biomass are converted to furfural (room for co-valorization)
- Typically 5 kg wood / kg LA, co-producing 0.4 kg FA and 2.4 kg char (dry basis)
- Carbon footprint: 0 kg CO_2 / kg LA -> Carbon neutral!
- Estimated cost price @ 150 kTon/y 75% lower than current technology!

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DSM Levulinic Acid feedstocks

Need commodities

- Available all year through
- Constant quality, preferably dried (indicative: moist <20 wt%)
- Good price (indicative plant gate price: <70 €/ton on dry basis with cellulose content >40 wt%).
- Local wood pellets could well qualify. Note that the price of oversee wood pellets (Canada, USA) on port of Rotterdam is 130 €/ton. Logistic cost (transport to local harbor, sea freight) could add up to 50-60 €/ton.
- Wood is Good: in fact an excellent cellulose containing raw material, with no concerns regarding water scarcity, use of fertilizer and hazardous pesticides and competition of cultivated land used for food…
- …and other ligno-cellulosic source may also serve the purpose very well, if produced sustainably.

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DSM Levulinic Acid feedstocks

Pellets are good formulations

- Pellets can be produced at small scale (farm or cooperation of few farms) and stored at large scale.
- Side streams can suitably be pelletized (like local sawmills do)
- Pellets are dense (wood pellets 650 kg/m3, wood chips 190 kg/m3), so low transport and storage volume (in ARRRA the wood pellet stock is about 50 MT).
- Pellets have good flow properties.

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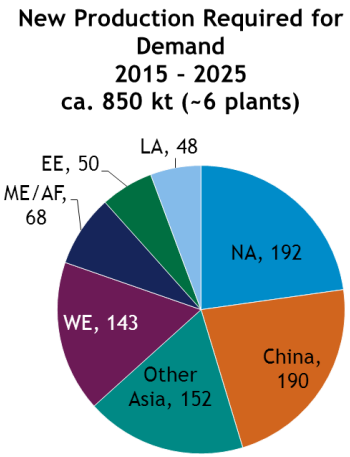
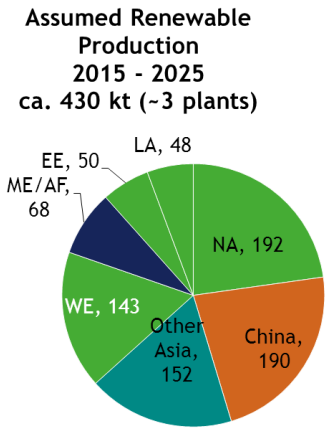
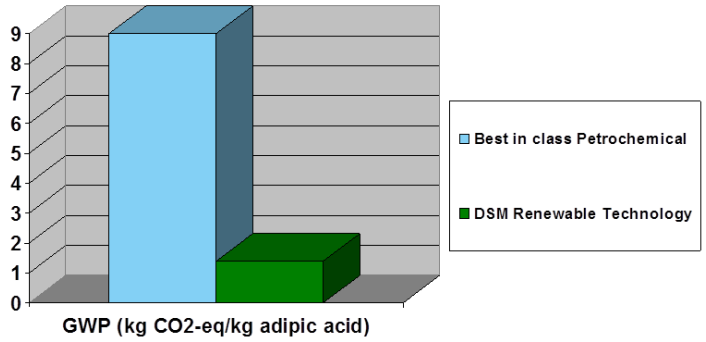
DSM Adipic Acid technology

Economically attractive, bio-based and very low carbon footprint

- Based on Levulinic acid (or gamma valerolactone)
- Estimated cost price below the commercial Adipic Acid technology (~1.3$/kg @ 50$/barrel oil)
- Substantial carbon footprint reduction of more than 80%
- Opportunity is the growing demand for bio-based polyamides (PA 6,6 and PA 4,6) for E&E markets and Automotive







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Route to full commercial scale

Estimated timelines and costs

Activity	Ready	BM→LA (M€)*	LA→GVL (M€)**	GVL→AA (M€)***
R&D support (depends on scope)	2016	1-2	1	2
Design pilot plant (30 t/y)	2016	1-2	1	2
Build (or revamp) pilot plant	2017	5	2	5
Run pilot plant	2018	5	2	5
Design specialty plant (5-10 kT/y)	2019	2	1	2
Build specialty plant****	2020-1	30	10	20
Run specialty plant	2022	15	5	15
Design commodity plant (100+ kT/y)	2022	5	2	5
Build commodity plant****	2023-4	250	40	150
Run commodity plant	2025			

* Biomass to levulinic acid
** Levulinic acid to gamma-valerolactone
*** Gamma valerolactone to adipic acid
**** Brown field

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