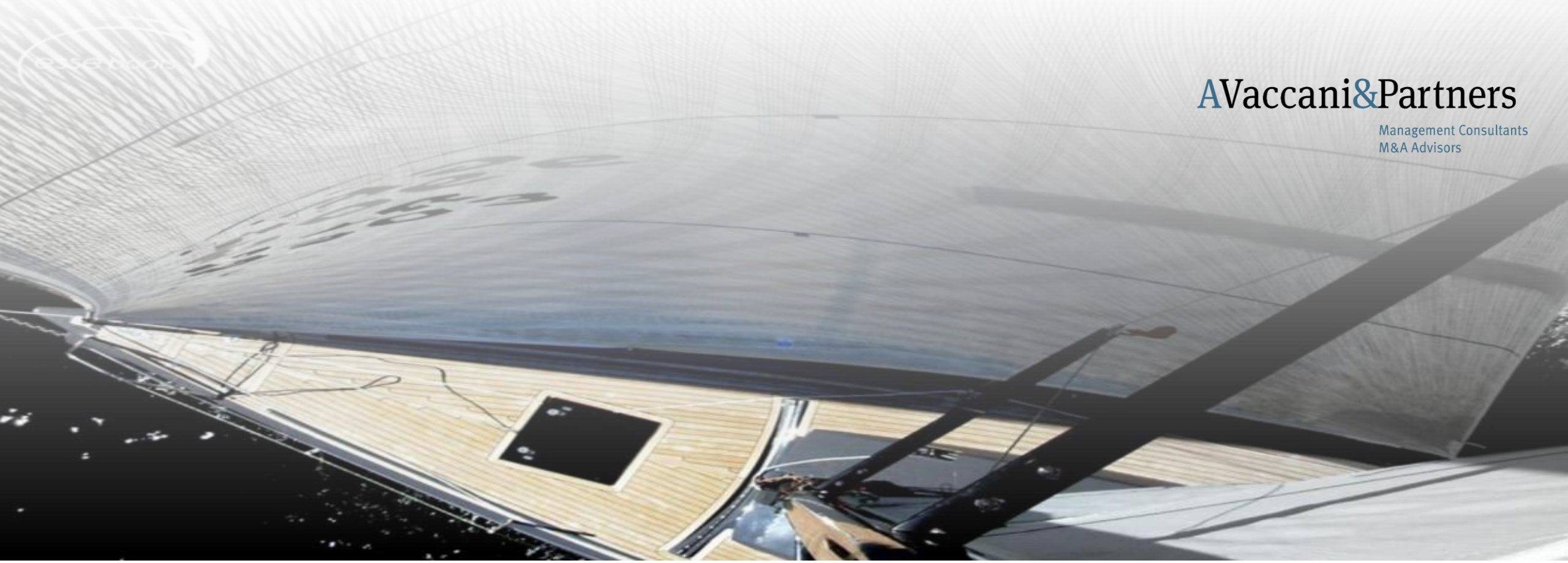

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International Market Developments in the Sewage Sludge Treatment Industry

Sewage Sludge Treatment

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About A. Vaccani & Partner (AVP)

AVP is an independent international management consulting company located in Switzerland, founded 25 years ago

- Member of the ICFG international M&A network with over 40 offices worldwide
- Key activities include
  - Strategy Consulting
  - Mergers & Acquisitions, Project Financing
  - Strategic Partnering
  - Specialized Research
- Unique combination of transaction orientation, management consulting competence and business experience
- AVP team located on three continents with complementary skills and business experience, highest standards with regards to professionalism and quality
- Long experience in working with national and international clients on cross border mandates

AVP has a well proven and renown track record in Renewable Energy & Environment (RE&E) and a well-qualified practice team

- Strong domain experts and dedicated research in three practice areas:
  - Sustainability, Waste Management
  - Energy
  - Water
- Executed over
  - 250 M&A and partnering mandates
  - 150 consulting mandates
- Extensive network of industry contacts, large international network of specialists
- Excellent references and partner network in Europe, Asia, USA
- Established toolbox (and database) for market research and industry analysis
- Unique knowledge of what is happening in the most attractive market segments

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- CEO ABB worldwide Business Area Resource Recovery
- CEO W+E Umwelttechnik AG
- Various Board / Advisory Board positions

Specialties

- Practice leader for AVP's waste, biomass, multi-fuel business
- Extensive experience with all aspects of international business development:
  - Strategy development and implementation
  - Mergers & Acquisitions (M&A)
  - Strategic Partnering and Licensing
  - Project development
- Personal access to many decision makers of global and regional leading market players

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Key Points for Today's Discussion

- Market drivers and sewage sludge volumes
- Disposal / treatment options
- Selected Technologies
- Market – Business Outlook

Global Need for Safe Management of Sewage Sludge is Growing Rapidly

- World population 7.5 billion and growing at rate of 1.13% (~226’000 per day)
- Urban population is 4 billion and expected to grow up to 4.7 billion by 2025
- 31 megacities out of 512 cities with population over 1 million
- Waste water treatment has high priority in environmental protection with high importance in large and small urban context.
- Sewage sludge production is proportional to waste water treatment volume
- Total sewage sludge generated world wide is approximately 75 million tons per year 2013 growing to approximately 103 million tons (+37%) by 2025
- Sewage Sludge related regulations are very sketchy
- Statistics are very inconsistent or often inexistent
- Actual sewage sludge treatment is not well documented

Source: Winnipeg Free Press

Factors Impacting the Market Development in Europe

Market Drivers

		Impact
National and EU Regulation	▪ EU regulation (water/waste) ▪ National frameworks for implementation	●
Increasing disposal costs	▪ Leading to an effective sludge management strategy	●
Potential revenue stream	▪ Energy recovery ▪ Recycled phosphorus from sewage can cover 20% of Europe's demand	●
Circular Economy	▪ Shift to reducing and reusing waste	◑

Market Challenges

		Impact
High cost of treatment technology & O&M	▪ Cheaper to reduce sludge volume than to treat it for reuse	●
High transportation cost	▪ Transportation of sewage sludge to treatment facility may be uneconomical	●
Lack of strong & effective governance	▪ Lack of expertise and human capacities ▪ Low implementation priority	●
Shortfall in funding for treatment	▪ Need for a more established new financing models	◑

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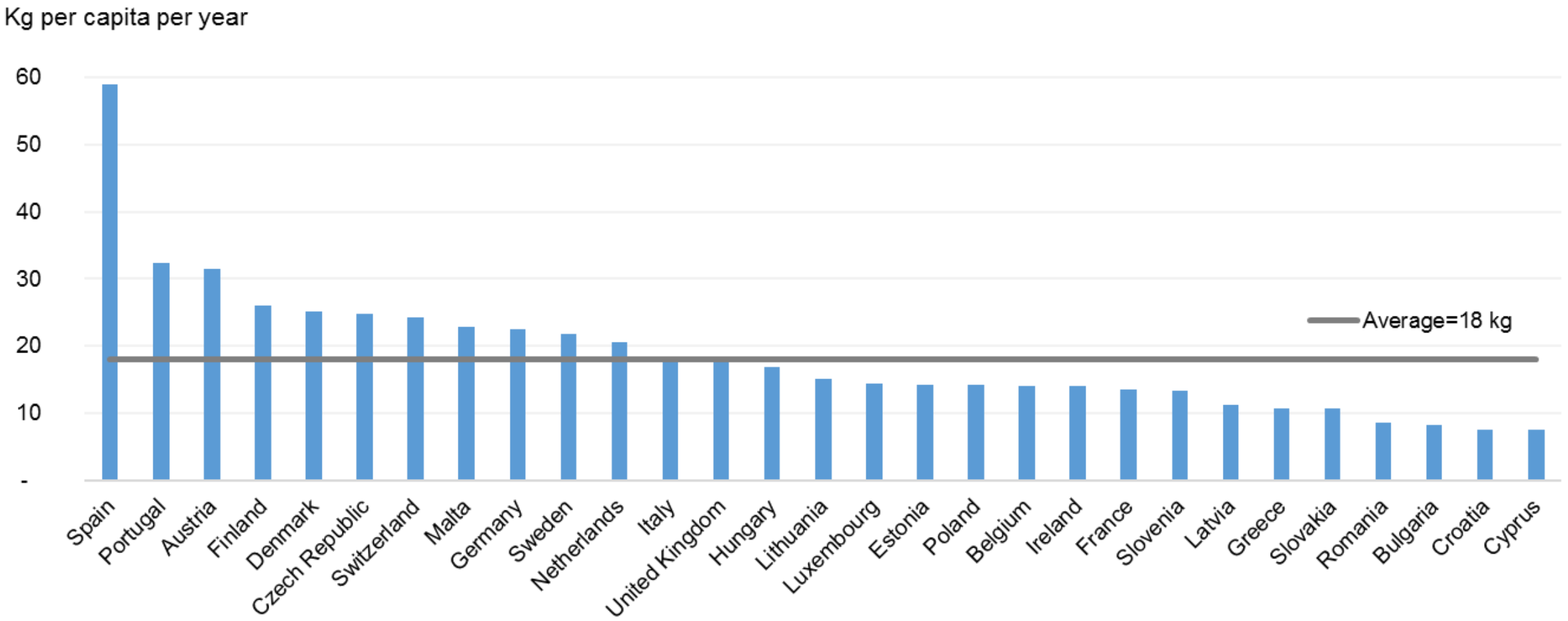
Per Capita Sewage Sludge Generation in Europe



Source: Eurostat, 2013 Data

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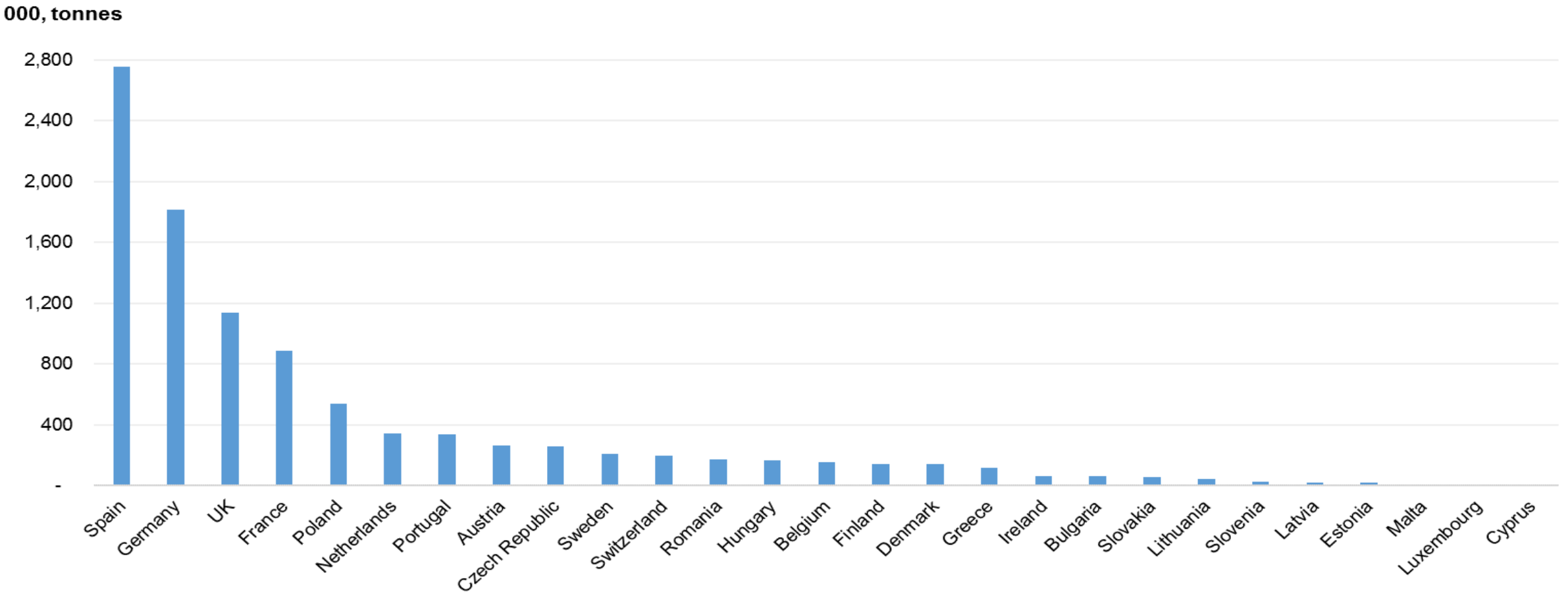
Annual Sewage Sludge Production in Europe



Source: Eurostat, 2013 Data

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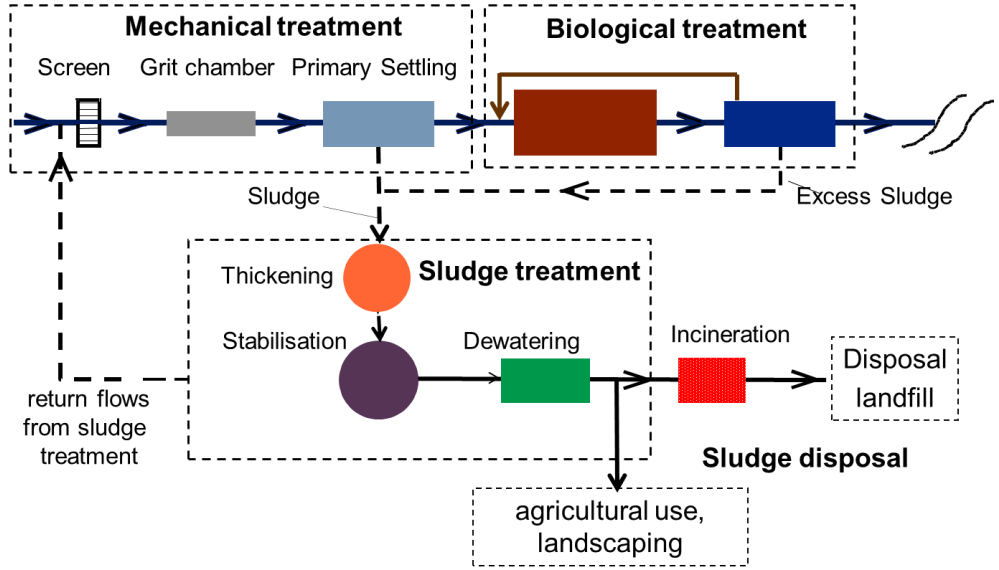
Sewage Sludge Treatment Options

	Options	Benefits	Constraints
Land Use	▪ Agriculture ▪ Reclamation ▪ Silviculture ▪ Forestry ▪ Amenity ▪ Horticulture	▪ Established policy ▪ Nutrients ▪ Organic matter ▪ Low cost/ low technology	▪ Voluntary ▪ Vulnerable ▪ Variable demand ▪ Quality ▪ Impacts ▪ Competition
Fuel Use	▪ Incineration ▪ Supplementary fuel for power and processes ▪ Gasification	▪ Renewable energy ▪ Low transport costs (if on site) ▪ Continuous process	▪ Public perception ▪ Planning controls ▪ Costs ▪ Emissions ▪ Ash disposal
Disposal Option (until 2020)	▪ Landfill – mono ▪ Landfill – co-disposal	▪ Low cost ▪ Low technology ▪ Fill and forget ▪ Enhanced CH_4 recovery	▪ Gas emissions ▪ Leachate ▪ Legacy ▪ Resource loss ▪ Void loss



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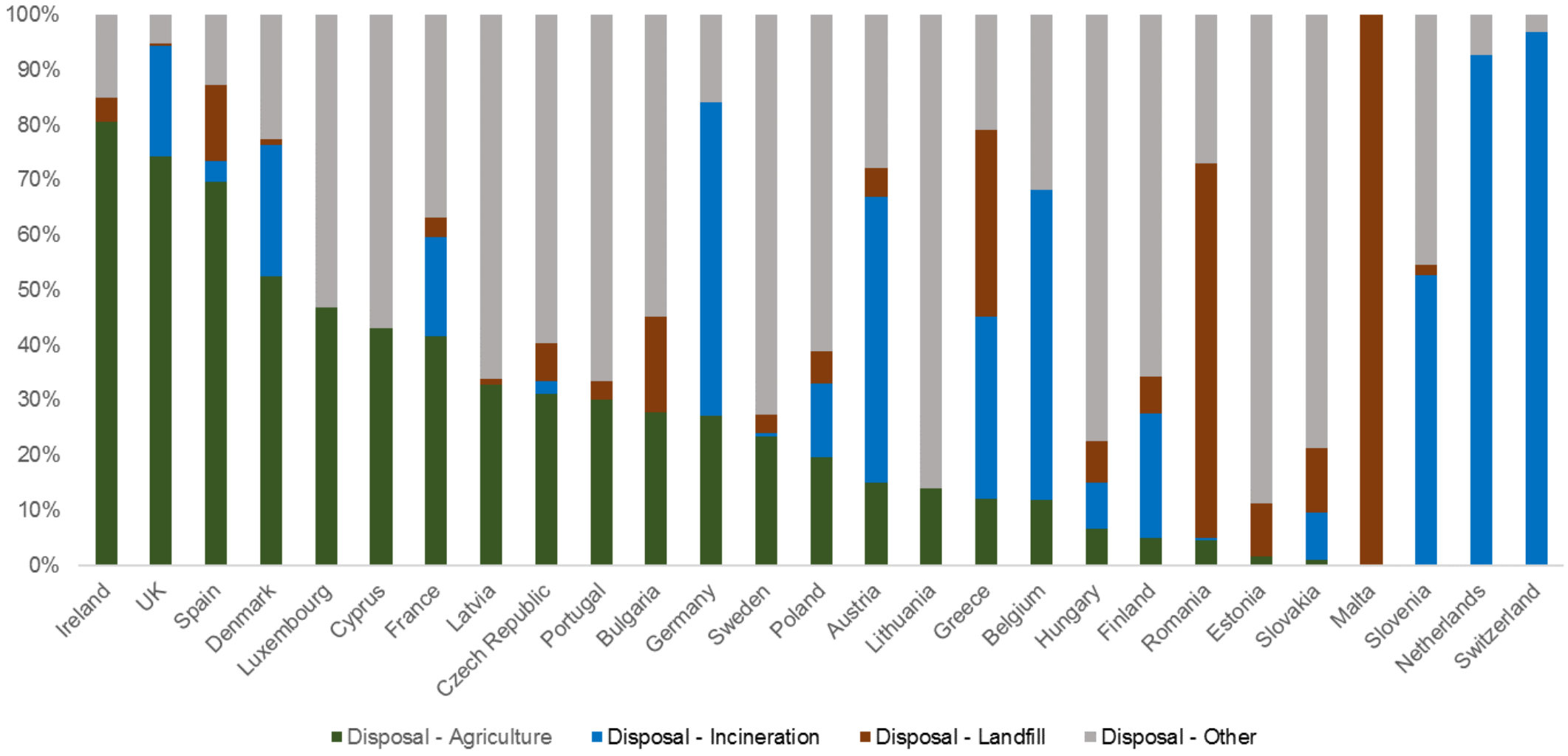
Disposal / Treatment Methods of Sewage Sludge in Europe



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Possible Impact of Legislative Changes in Europe

- **Waste framework directive (2008/98/EC)**
  - According to this Directive sewage sludge is a waste and has to be treated, recycled, reused and/or disposed off accordingly
  - Waste legislation (risk management) does not favour use of sludge in agriculture
  - Waste management is a business and accordingly the legislation is strongly addressing private initiative and favours market economy
  - There is no provision for the relationship between WWT and sludge treatment/disposal
  - Waste legislation is very different form water legislation for several reasons (causes conflicts)
- **Hygienic aspects get more relevant again**
  - Infection transfer at farm level (MCD, etc.),
  - Transfer of antibiotic resistance, legionella?
  - Even there is no report on hygienic problems with sludge application in agriculture over the last decennia.
- **Increasing trend to recognize sludge (and WW) as valuable resources. (Water, P, N, org. C,..)**
  - 80 to 90 % P- removal at most of the treatment plants in central Europe (having no P- ores)
  - P- recycling is a matter of intensive research in EU.
  - EU commission is preparing a P-policy

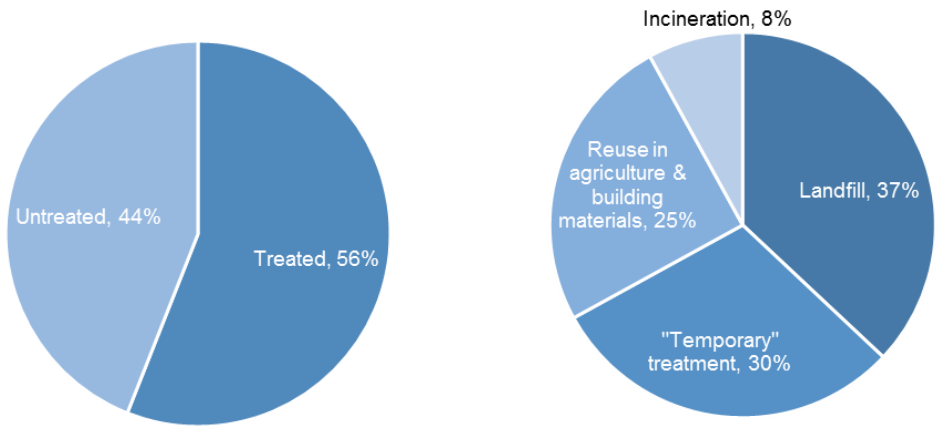
Other Markets: China – 28 million Tons of Sewage Sludge Annually

- Total sewage production is 71 billion tons, of which 20 billion tons - industrial wastewater and 51 billion tons municipal sewage. The top ten provinces account for 44 billion tons.
- The industrial waste water declined since 2008, while the municipal sewage grew annually by average 5%.
- More than 60% of all Chinese are now living in cities.
- In 2014, Chinese sewage plants produced 28 million tons sewage sludge. 56% were treated by “professional” qualified companies, via landfill (37%), incineration (8%), conversion to fertilisers and building materials. Another 1/3 was treated “temporarily”. Remaining disappeared without clear explanation.
- Landfill remains the cheapest method, followed by fertilisation. The drying process before incineration is the most expensive.
- Many companies are fighting for the fat cake, collecting the fees for "treatment".

STPs, 2014

	Prefectural Level	County Level
Number of Cities	287	374
Urban sewage	~ 40 bln m^3	
Number of STPs	1 808	1 554
Sewage produced	28 mln tons	
Treated Sewage Capacity per day, m^3	131 mln m^3	~29 mln m^3
Annual growth of treated capacity	5.1%	7%
Total Sewage treated	90%	82%

Only about 18% of Sewage Sludge Actually Treated



Source: AVP Analysis

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Other Markets: India – Only About 30% of Sewage Treated

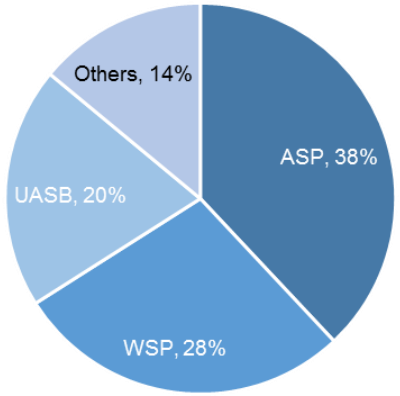
- 62,000 MLD (22.6 billion tons per year) sewage generated by Urban India
- Treatment capacity is 23,277 MLD (8.5 billion tons per year) i.e. 37%
- 816 Municipal STPs are “commissioned”, of which only 522 in operation
- Thus, only 18,883 MLD (6.8 billion tons per year) sewage is treated and 70% of sewage is left untreated
- Class I cities (population 100k+ and Class II cities (50k+)
  - Generate: 38,255 MLD
  - Treat: 11,787 MLD (30%)
- Approximately 6 million tons of sewage sludge is generated annually. We have no information about its treatment and/or disposal.

STPs per State - one Third of STPs Not Operational

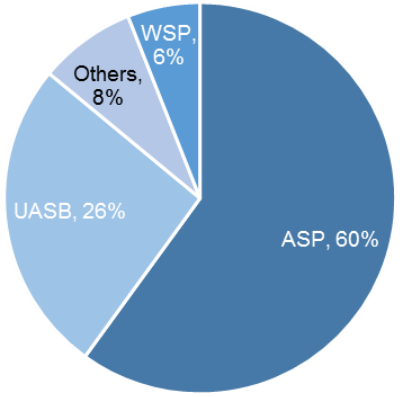
State/UT	Punjab	Maharashtra	Tamil Nadu	Uttar Pradesh	Himachal Pradesh	All India
Capacity of Municipal STPs (MLD)	1 245	5 160	1 800	2 647	115	23 277
Total Municipal STPs	**86**	**76**	**73**	**73**	**66**	**816**
Operational Capacity (MLD)	921	4 684	1 141	2 372	80	18 883
STPs Operational	**38**	**60**	**33**	**62**	**36**	**522**
Non-Operational STPs	4	10	1	7	30	79
Under Construction STPs	31	6	28	3	-	145
Proposed STPs	13	-	11	1	-	70

Technologies in Use in India

based on number of STPs



based on capacity of STPs



Source: Encito Advisors

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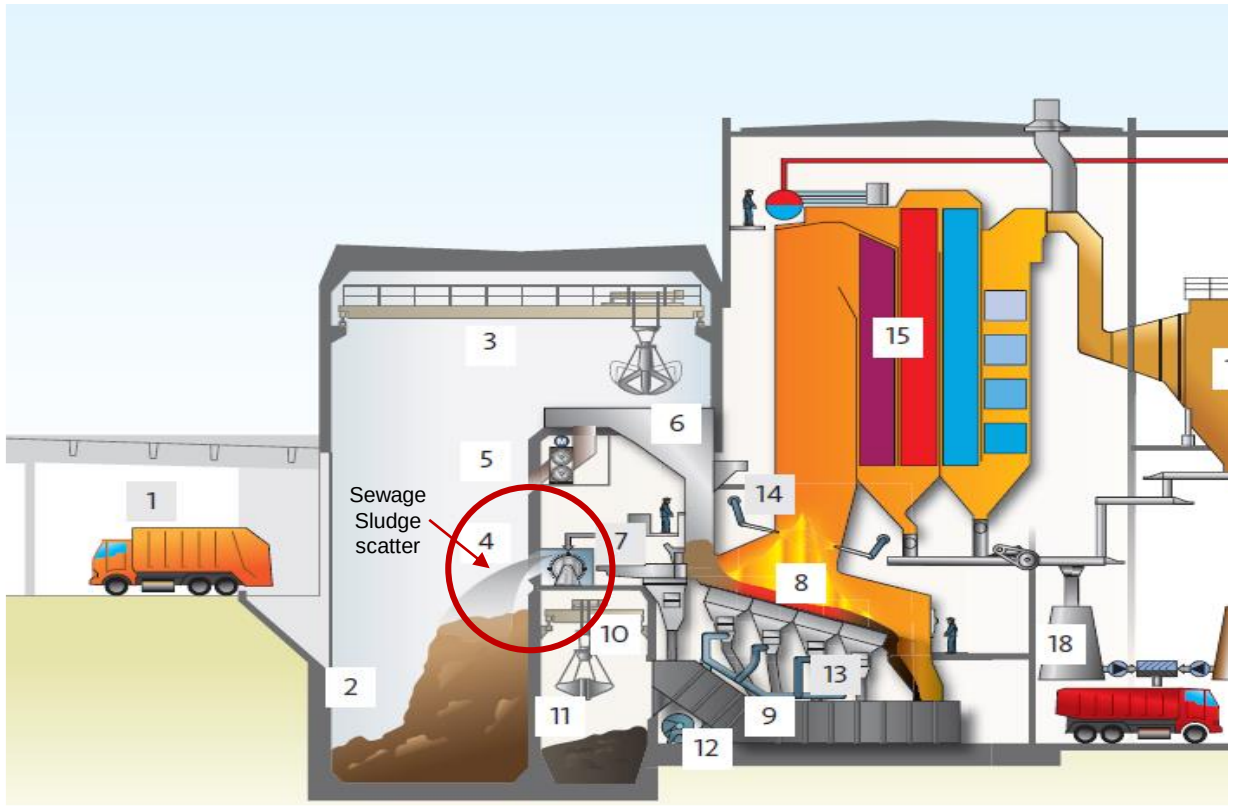
Co-incineration of Sewage Sludge in MSW Plant (Germany)

Obvious energy recovery choice in line with Waste Legislation and "reasonable marginal cost"
Some operational benefits with MSW plants (e.g. RdF, SRF)
P recovery difficult because of "diluted" incineration ash



Source: Hitachi Zosen Inova

Example of Bamberg EfW Plant

- Co-incineration of 12-13'000 tpa of sewage sludge with app 30% DS together with household, commercial, and bulky waste
- Three process lines with total capacity of approximately 144,000 tpa
- The sewage sludge is scattered into the waste pit, mixed with the other waste, and incinerated together with the MSW on the grate
- Other co-incineration options:
  - Spreading on the grate
  - Spreading on the feeding hopper

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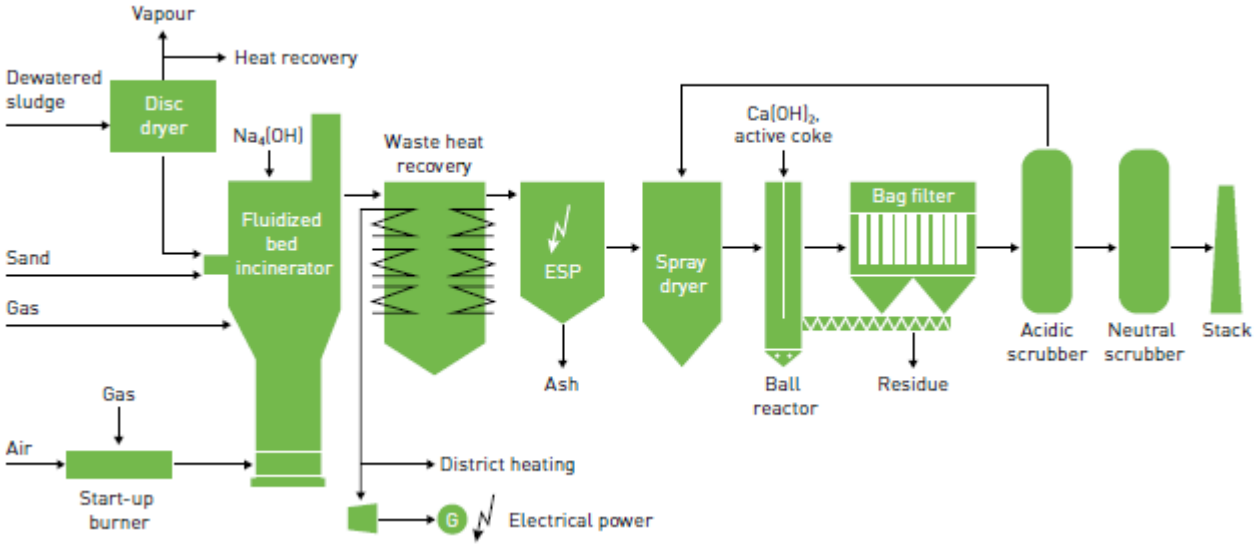
Mono-incineration of Sewage Sludge (Switzerland)

Prevalent energy recovery choice in markets that avoid/ban agricultural use, in line with EU waste legislation
High cost – requiring large plants with regional reach
Mid term goal to recover P from incineration ash (considered feasible because of high P concentration in bottom ash)

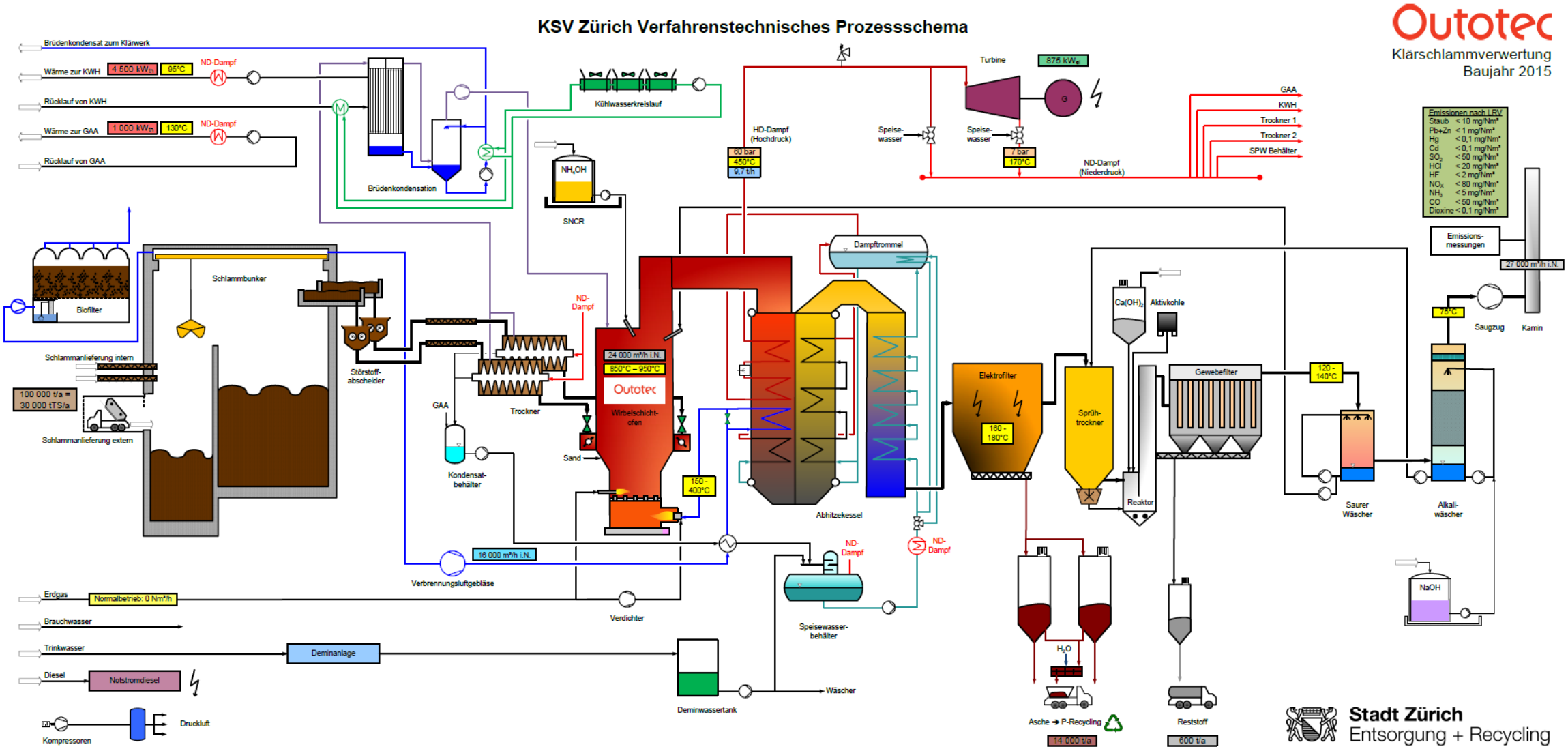


Source: Outotec

Example of Zürich Sewage Sludge Incineration Plant

- Fluidized bed incinerator for 100’000 tpa sewage sludge with DS of 22-30%
- Steam boiler 450C, 60 bar
- Steam turbine 900kWel for internal consumption
- Supply of app 5MW of heat to district heating network

Mono-incineration of Sewage Sludge (Switzerland)



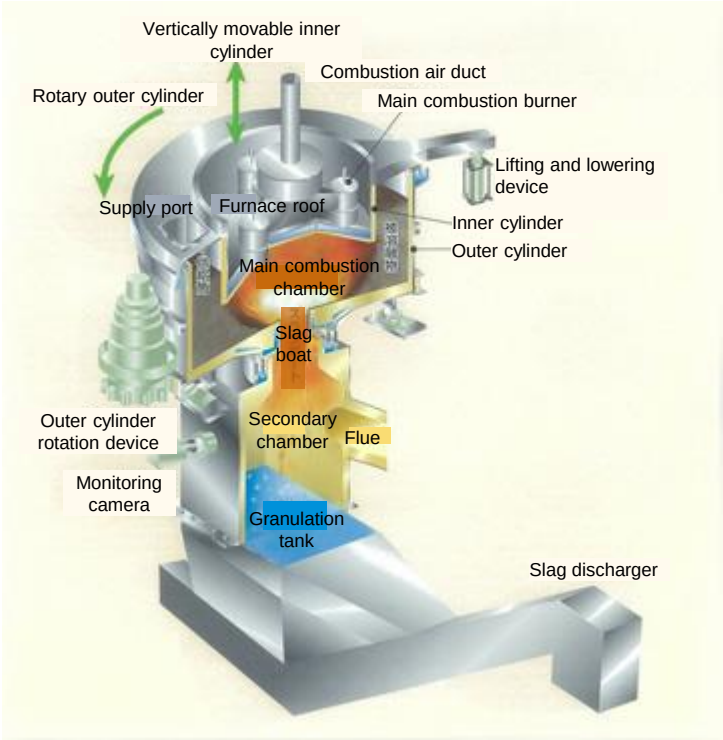
Source: Outotec

Kubota Surface Melting System (Japan)

Kubota Surface Melting Furnace

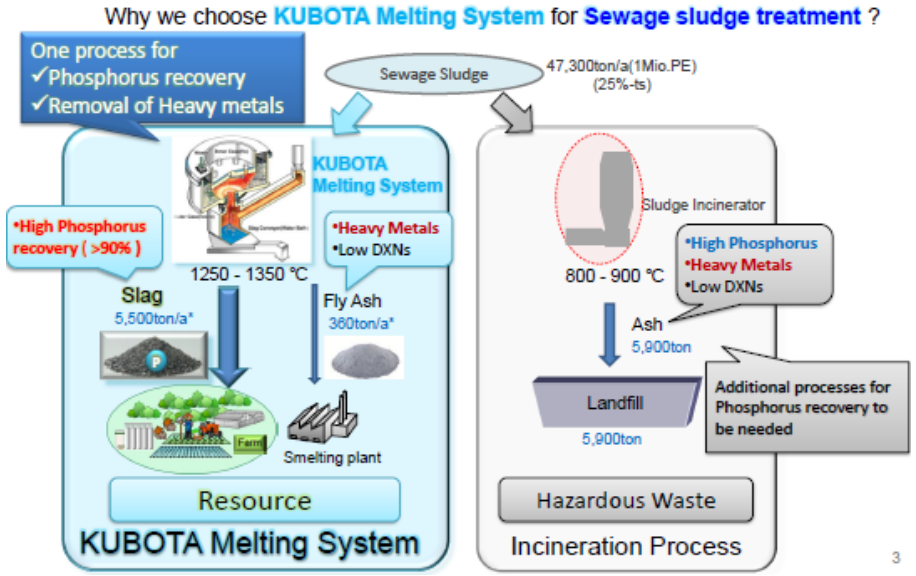
Key technology for separation and purification from wide variety of wastes

- Wide variety of wastes are acceptable.
  - Wet / Dry
  - Combustible / Incombustible
  - Bulky wastes : after treatment (< 30mm)
- Continuous and stable feed:
  - The wastes are fed into the furnace by continuous outer cylinder rotation.
- High temperature treatment: 1250-1350° C
  - Organic hazardous substances such as DXNs, PCBs, POPs are decomposed in the furnace.
- Recovery of Resources
  - ✓ Separation of heavy metals from slag:
    - Heavy metals such as Pb, Cd, Zn, HG are separated from slag and condensed into fly ash.
  - ✓ Immobilization of phosphorus in slag with high recovery rate (>80%).
- ✓ 40 years history, more than 30 track records



Schematic diagram of KUBOTA Surface Melting Furnace

Source: Kubota



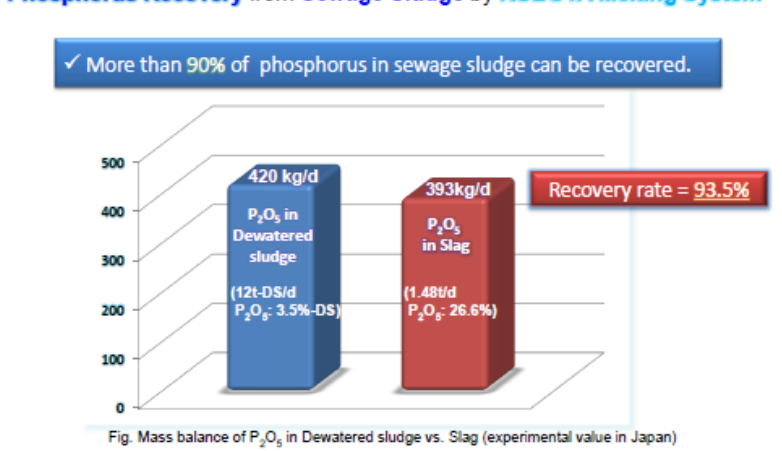


Fig. Mass balance of P_2O_5 in Dewatered sludge vs. Slag (experimental value in Japan)

WWTP for sewage treatment plant with capacity of200 thousand PE.
We have 11 reference plants and 7 under operation since 1979.

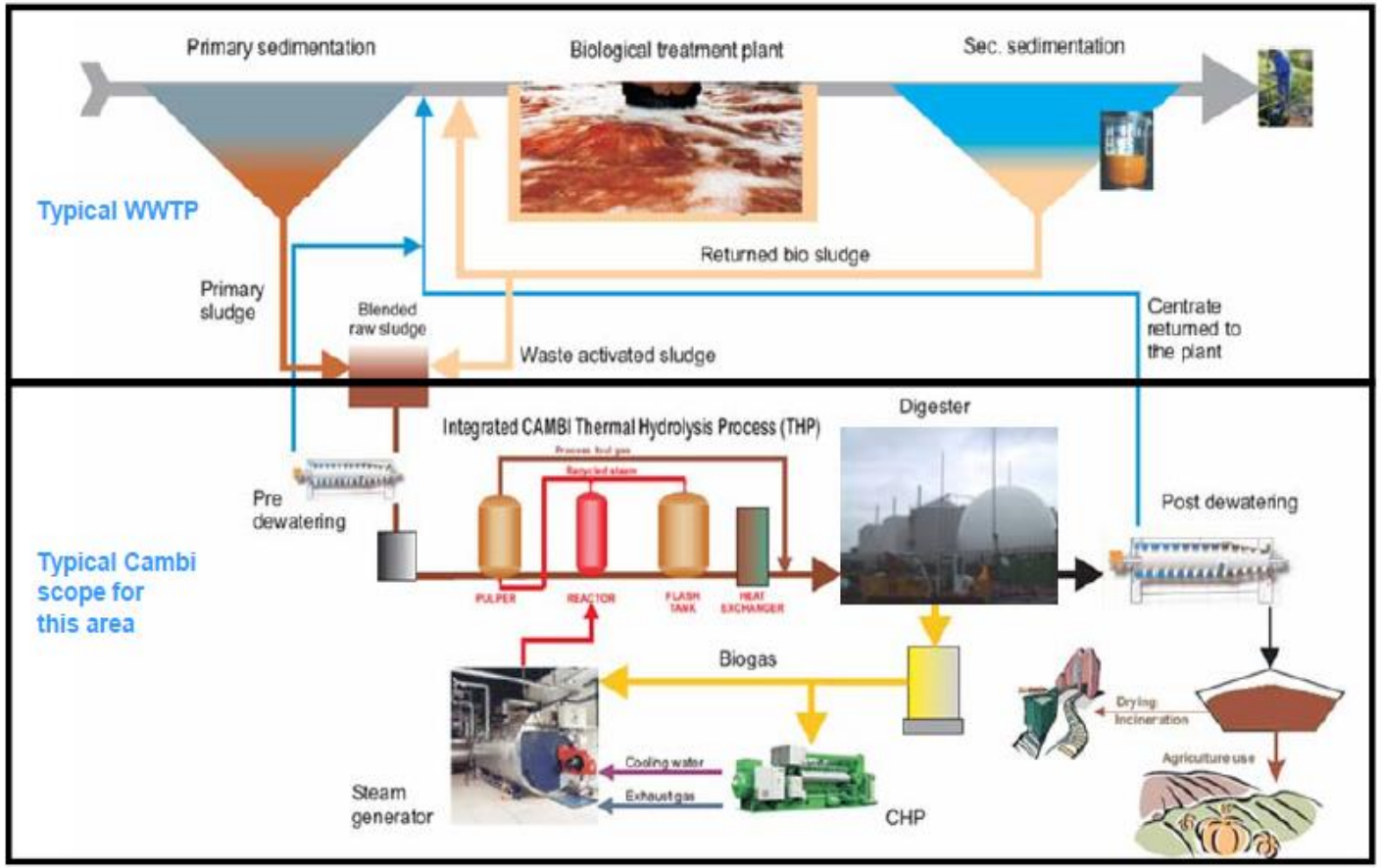
4

Advances in Digestion Lead to Reduction of Sewage Sludge Amount

Aerobic Digestion	Anaerobic Digestion (Mesophilic)	Advanced Anaerobic Digestion
▪ Low CAPEX for plants under 5 MGD (220 L/s) ▪ Relatively easy to operate ▪ Minimal unpleasant odors ▪ Volatile solids destruction is approximately equal to that observed in anaerobic digestion as long as the ratio of primary solids to biological solids is less than 0.50.	▪ High Methane content can be used for heat and power ▪ Approximately 25- 45% (weight basis) of the influent sludge solids are destroyed ▪ Digested sludge is soil conditioner containing N and P, other nutrient and stable organic matter ▪ Pathogens and parasite ova associated with the raw sludge are inactivated	▪ Thermophilic Anaerobic Digestions (TDA) ▪ Two-phased and temperature-phased (TPAD) ▪ Digestion pre-processes, e.g. Thermal Hydrolysis (TH)
▪ Poor mechanical dewatering characteristics of the aerobically digested sludge. ▪ High power costs to supply oxygen, even for very small plants. ▪ Performance is affected by type of sludge, temperature, location, and type of tank material.	▪ High CAPEX due to large covered tanks, pumps, heat exchanges and gas compressors ▪ Hydraulic detention time typically 15 days	▪ Two decades of development ▪ Some winners, some losers ▪ Extended/staged thermophilic (TPAD) operated in some places with success, in other places not so much ▪ TH – highly concentrated recycle stream

Cambi – Thermal Hydrolysis Process (Norway)

Typical Cambi™ Integration with WWTP



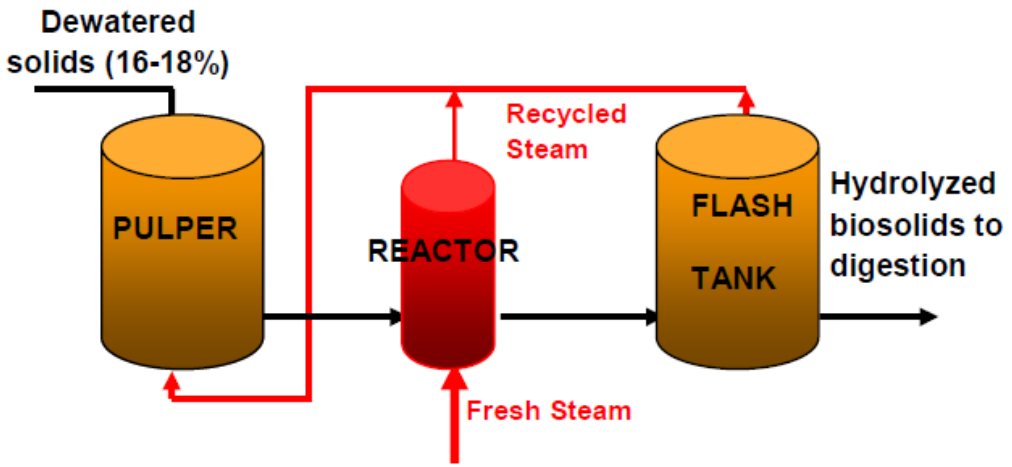
Source: AVP internet research

Typical Benefits Thermal Hydrolysis

- Increased biogas yield and methane content
- Up to 60% volatile solids are destroyed
- Improved dewaterability (dewatered cake approx. 35% DS vs. 24% for mesophilic)
- Improved biodegradability

Cambi – Thermal Hydrolysis Process (Norway)

Main Components of a Cambi™ System



B – 2 (2 m³ reactor)	B – 6 (6 m³ reactor)	B – 12 (12 m³ reactor)
Small size projects ▪ Standardized package unit ▪ Pre-assembled & pre-tested ▪ Containerized unit	**Medium-large size projects** ▪ Standardized package unit ▪ Pre-assembled skids	**Extra large size projects** ▪ Custom-made ▪ On-site construction
5 – 20 tDS/day	20 – 80 tDS/day	60 – 500 tDS/day

Source: Cambi and AVP internet research

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Market Outlook Europe

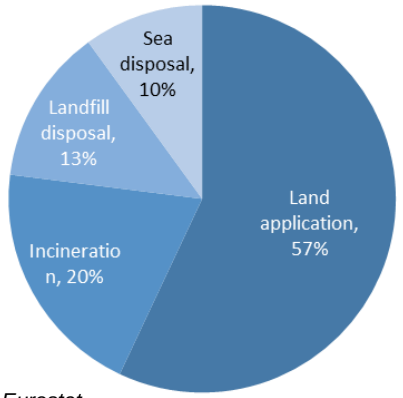
- 86% of EU 15 and 71% of EU 27 connected to sewage system
- Total sewage sludge production is about 10 million tons per year (DS) – expected to remain stable for the next 10 years
- Impact of Waste Directive favouring energy recovery vs agricultural usage and P recovery will create some market opportunities
- Dry nutrients as a treated sludge product
- Sludge dewatering technology is likely to grow in the medium term
- Commercial sludge trading market in 2020 in the UK
- Production of electricity from AD is expected to grow

European sludge treatment equipment market

	2016 Revenue (bln Euro)
Sludge thickening	~1.1
Sludge dewatering	~1.5
Sludge incineration	~0.5
Sludge drying	~0.6
Total	**~3.7**

Source: Frost & Sullivan, 2016

Sludge disposal and treatment in Europe, 2014



Source: Eurostat

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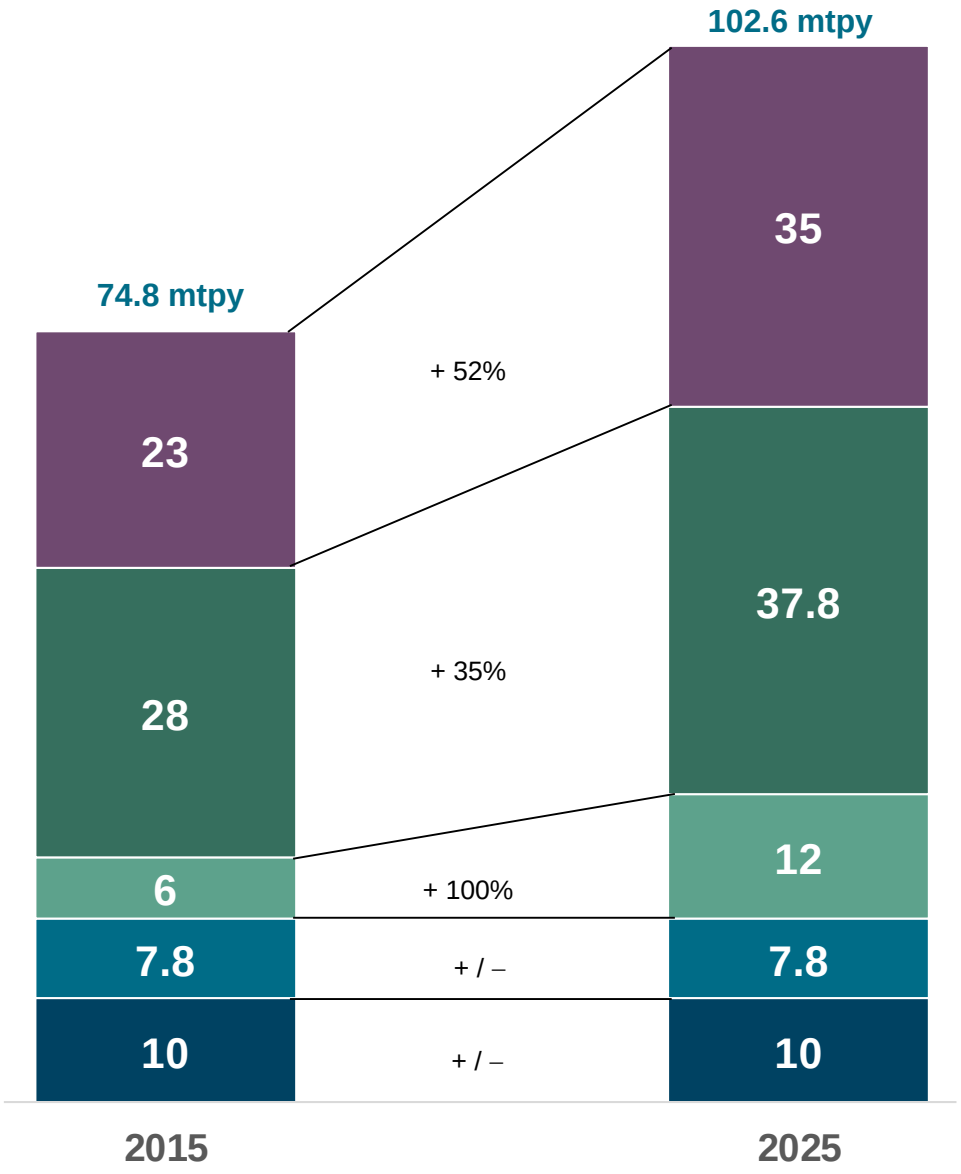
Global Market Outlook



Rest of World

Most attractive growth markets:
- South East Asia: Thailand, Malaysia, Indonesia
- Japan: 80% incineration moving to P recovery
- MENA
- Latin America and Caribbean

Contract models:
- "Service model"
- PPP
- EPC

China

- Only about 30% of sewage sludge "orderly" treated
- Thereof 1/3 landfilled
- Strong market growth
- Likely via "service model" and/or PPP schemes
- Actual market growth dependent on "political preference"

India

- Urban growth
- Utilization of "existing/planned" capacity
- Capacity build up
- Likely via PPP schemes

North America

- Focus on minimizing sludge volume (adv. AD)

Europe

- Transition to more energy recovery, less agriculture

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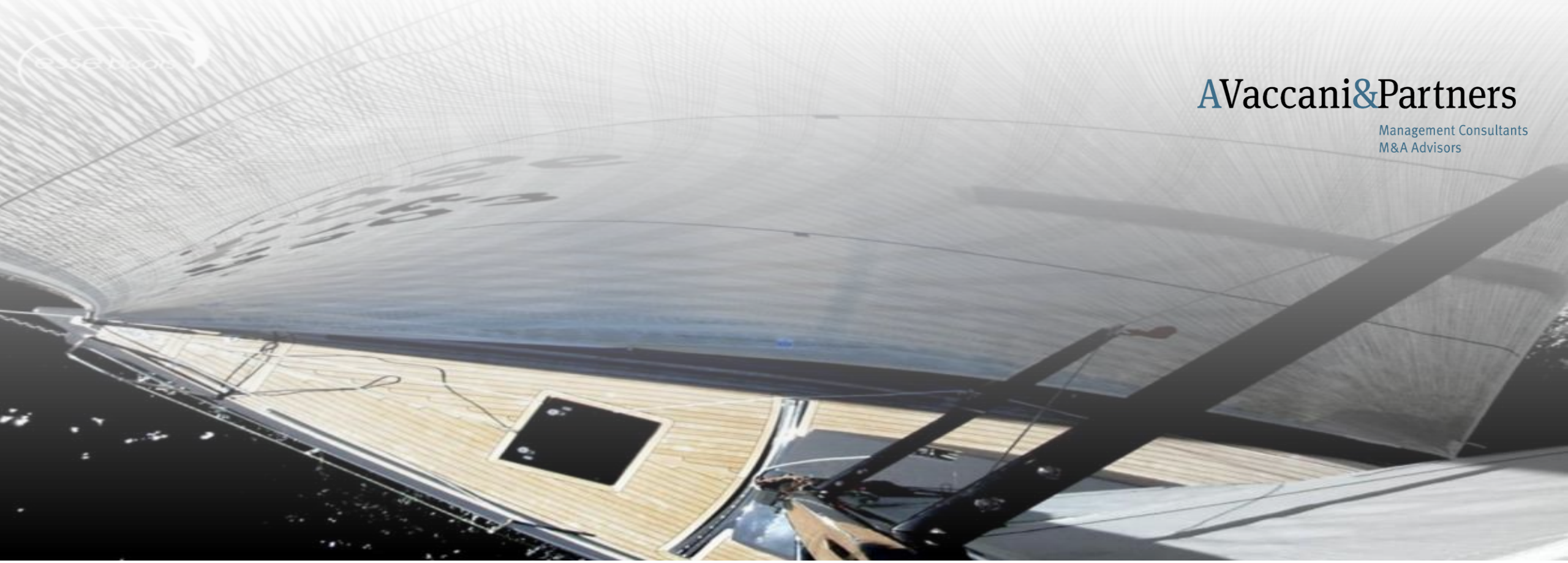
Key Strategies for International Business Development

- Technology/know-how base in Europe, US/Cd, Japan – with no significant market growth
- Growing markets: China, India, SEA, Latin America, others
- Strategic approach
  - Selection of strategic target markets / strategic growth plan
  - M&A
  - Strategic partnering (with localization)
  - (Licensing)
- Key success factors
  - Project development
  - CAPEX in line with market affordability
  - Localisation/globalization of supply chain
  - Maintain control of core know-how



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Thank you for your attention – QUESTIONS?

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