

ENGINEERING  
TOMORROW

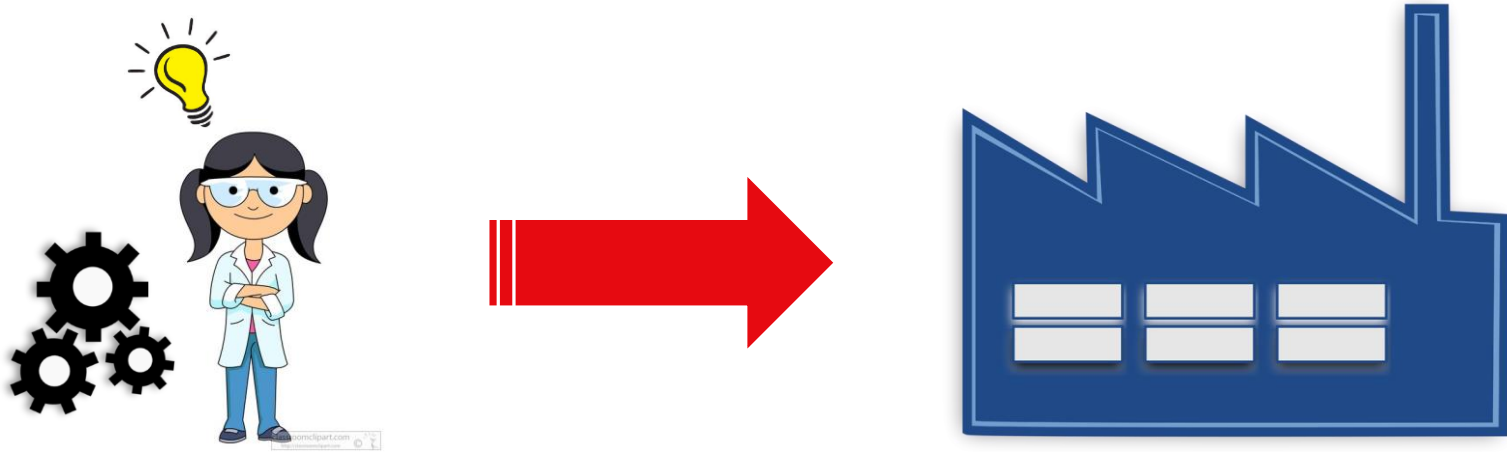
*Danfoss*

# Digital Displacement<sup>®</sup> Technology

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Danfoss Power Solutions



# Introduction – an innovation challenge



How to go from a bright idea to a real product?

Customers won't commit to buy a product that doesn't exist, and suppliers won't create a product without a customer to buy it.

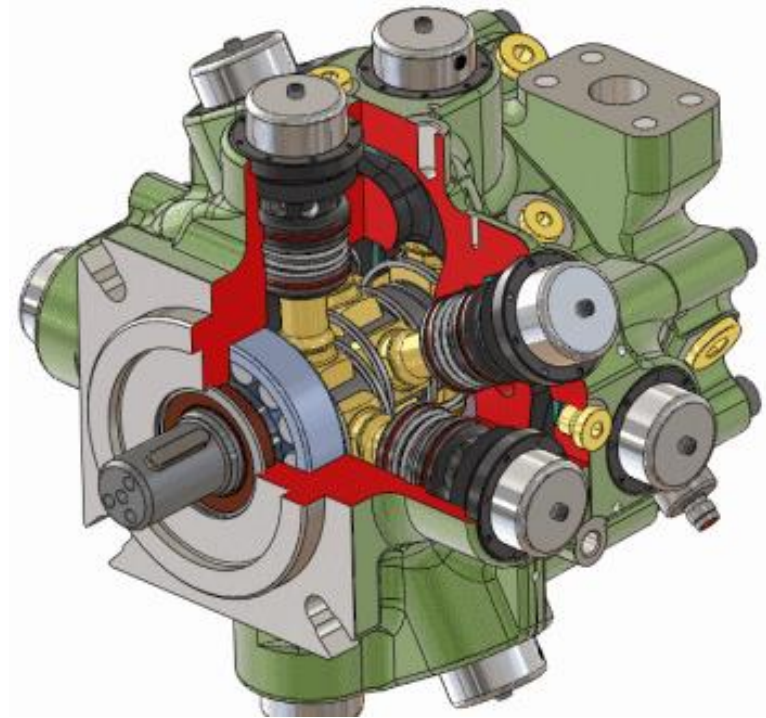


# Digital Displacement<sup>®</sup> Technology

- Radial piston design
- Digital control of individual pistons

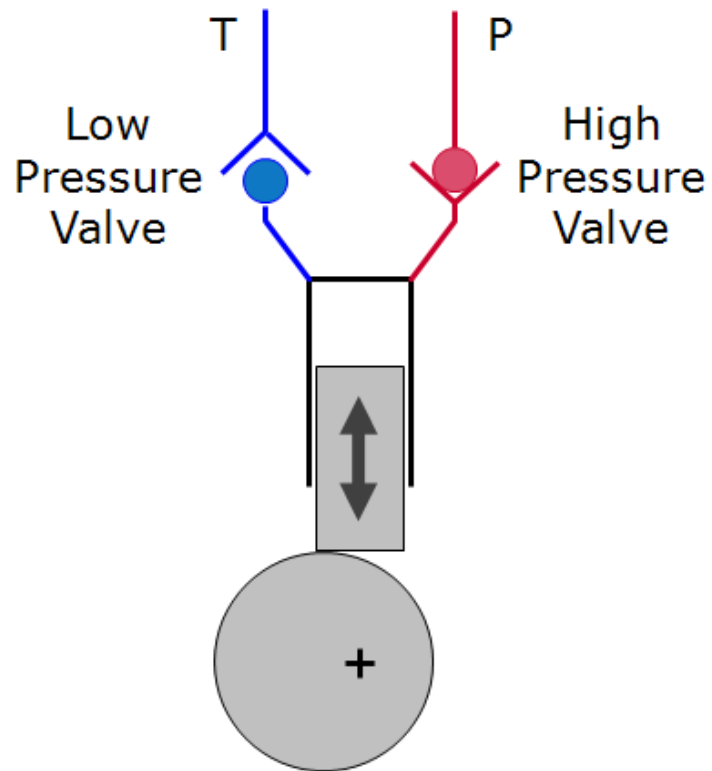
## Benefits

- High efficiency, low idle losses
- 420 bar continuous operation
- Fast and accurate response
- Control modes and parameters are electronically tunable
- Capable of multiple output ports



Digital Displacement<sup>®</sup> is a Registered Trademark of Artemis Intelligent Power Ltd.

# Digital Displacement<sup>®</sup> Technology

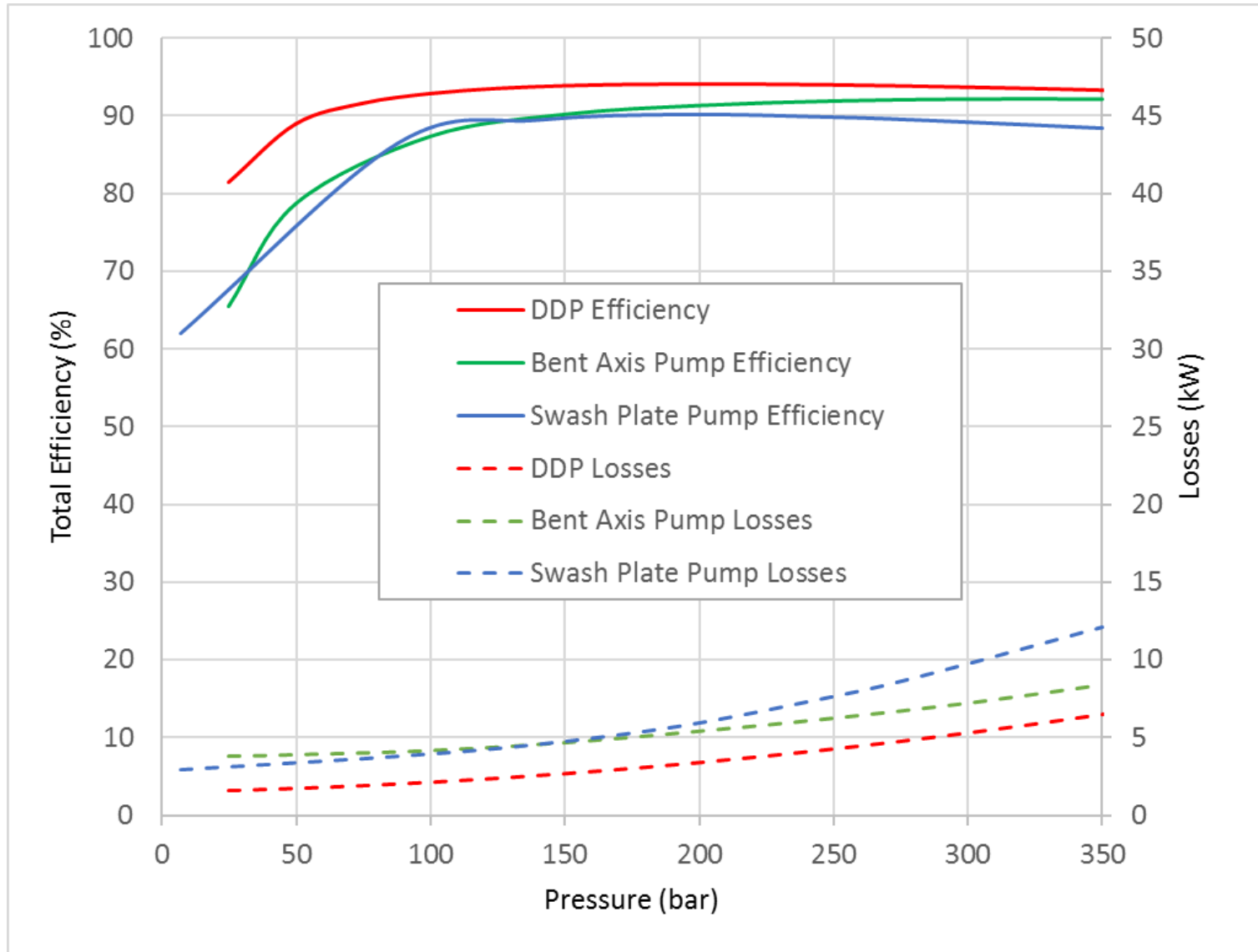


	Low Pressure Valve	High Pressure Valve
Pump (DDP)	Actively Controlled	Passive Component
Pump/Motor (DDPM)	Actively Controlled	Actively Controlled
Motor (DDM)	Actively Controlled	Actively Controlled

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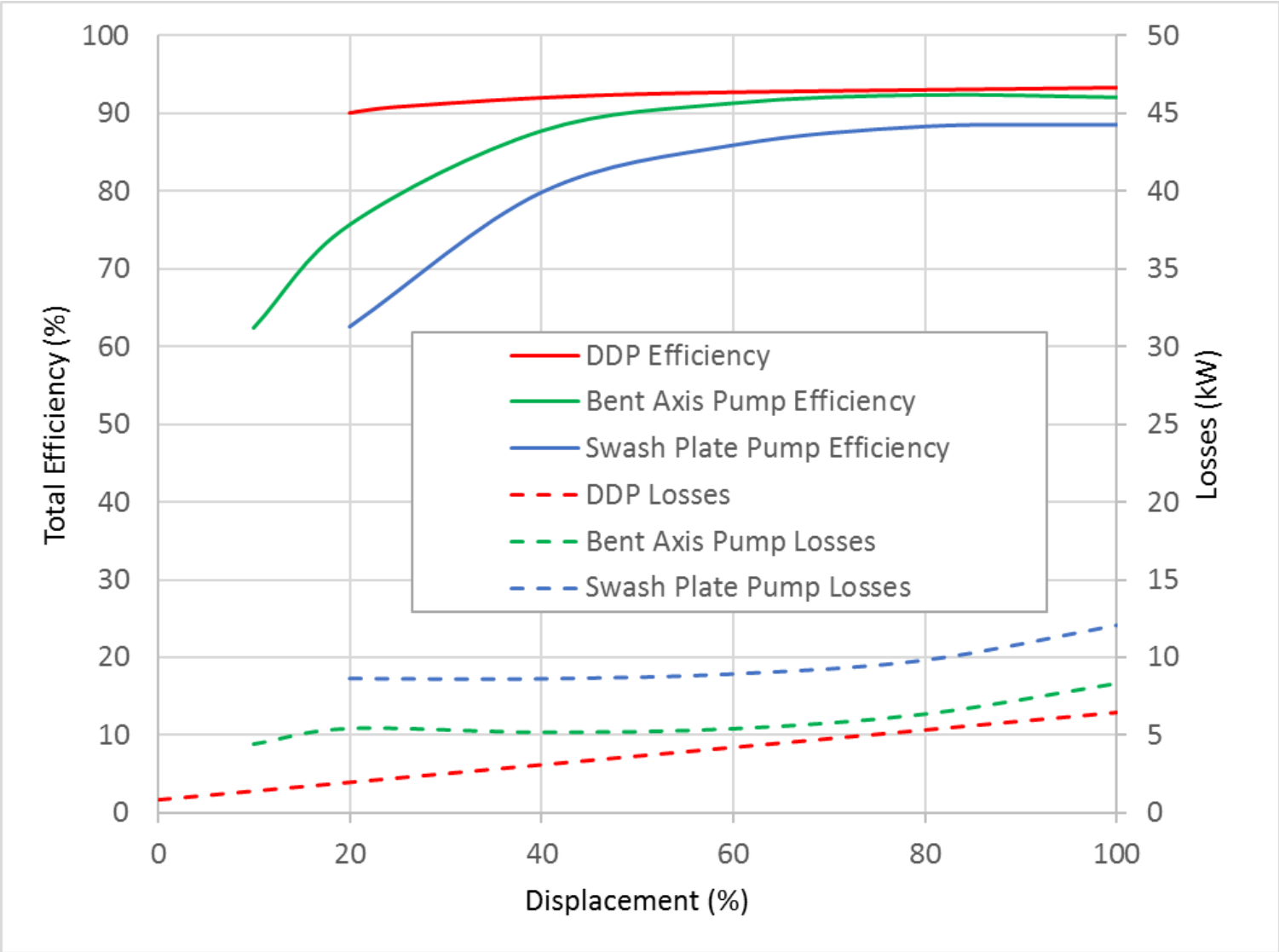
# Efficiency & Losses

100% displacement, 1800 rev/min



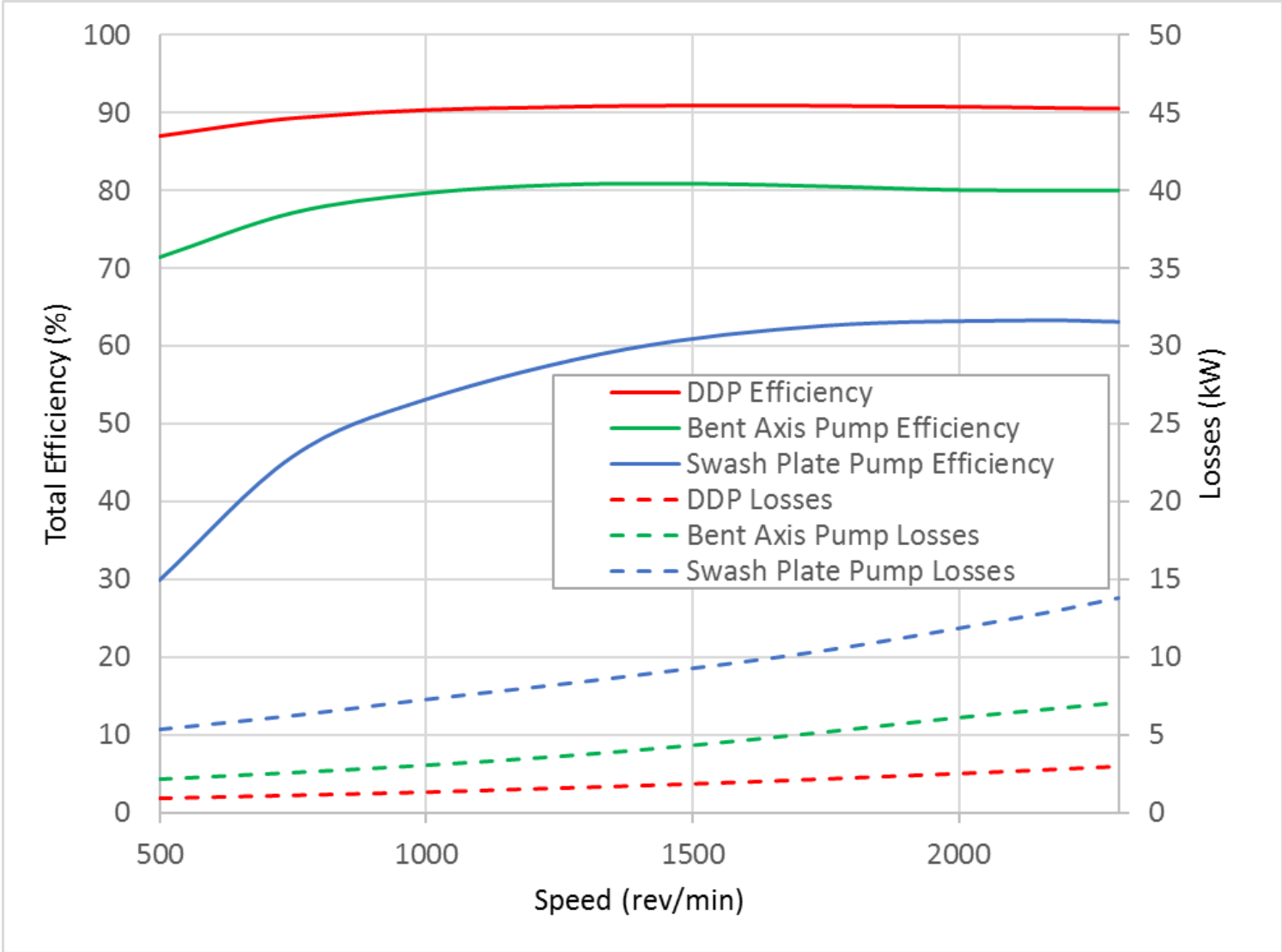
# Efficiency & Losses

350 bar, 1800 rev/min



# Efficiency & Losses

350 bar, 25% displacement



# About Artemis



The World's  
Largest Floating  
Offshore Wind  
Turbine... has a  
DD transmission



7MW



10kW

100 kW

1MW





# History of Digital Displacement

- 1984 – First concepts published for Wave Energy generator
- 1990 – First prototype, 18 cc/rev axial piston design
- 1994 – First radial piston design, formation of Artemis Intelligent Power
- 1998 – 1.5kW pump powerpack demonstrated
- 2003 – 6.0kW DDP propel system demonstrated
- 2004 – Aerial work platform demonstrated
- 2008 – BMW hybrid car: uses half the fuel of a manual transmission on EU city cycle
- 2011 – AIP demonstrates 1.6MW transmission
- 2014 – Hybrid city bus
  - 7 MW wind turbine begins operation in Scotland
  - First sale of 96 cc/rev DD industrial pump
- 2015 – 7 MW wind turbine begins operation off the coast of Japan
- 2016 – DD excavators



*The first full-size DD off-highway vehicle at Danfoss*



*E-dyn96 and its controller*



*The first DD power-pack*



*The first DD vehicle at Danfoss*



*BMW with DD Hybrid System*



*1.6MW DD Wind Transmission*

*The world's largest floating wind turbine and the world's most powerful hydrostatic transmission*



*7MW DD Wind Transmission*

# Tracked Excavator Demonstration

- JCB JS160 tracked excavator
- 93 kW engine, 17 tonne machine weight
- 2x96cc DDP replaced 2x80cc axial piston pumps
- Results in eco mode:  
10% more productive and  
16% to 21% less fuel
- Results in productivity mode:  
28% more productive and  
10% less fuel



# Wheeled Excavator Demonstration

- 11 tonne wheeled excavator
- 75 kW engine
- 96cc DDP replaced 95cc axial piston pump
- Demonstrated operation with load sensing system, multiple pump flow control algorithms
- Danfoss system integration



# Conclusion – the case for DDP

- Technology readiness – continuous operation since 2014
- Market readiness – think about energy efficiency, electrification, IoT
- Unprecedented efficiency plus fast and accurate control
- Strong partnership between Danfoss and Artemis

How to bridge the commercialization gap?



Iterate. Start small and accept risk.

*Danfoss*