M. Gillis, M. de Feber

The HUULC Project
Feasibility Study of a Hydrogen Powered Unmanned Ultra Large Cargo Aircraft

EWADE 2015, Delft University

The HUULC

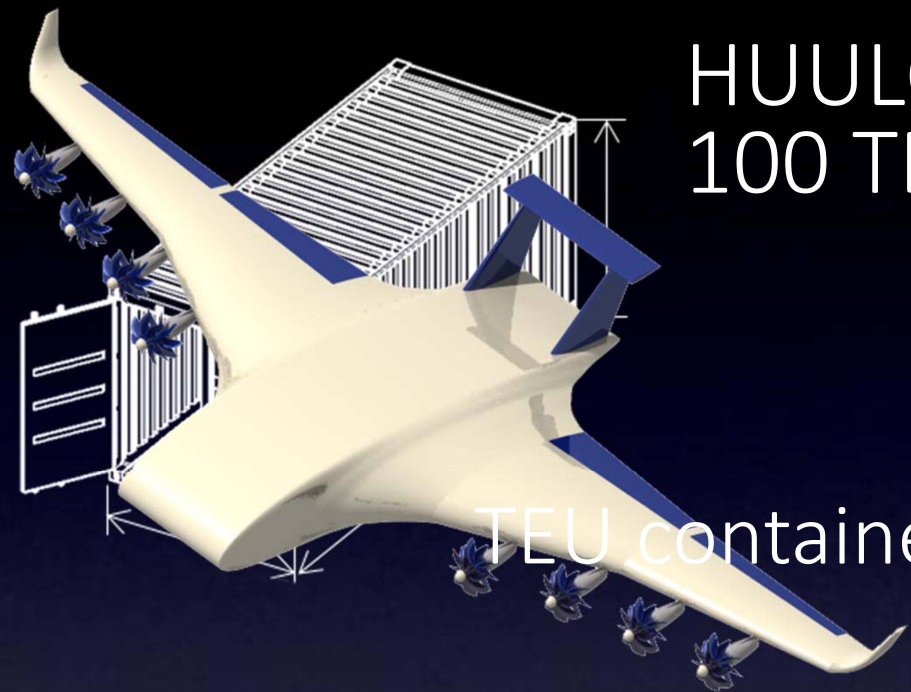
Hydrogen

Unmanned

Ultra

Large

Cargo aircraft



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The HUULC

Wingspan	200 m
Payload	1,200 ton
Max. take-off weight	2,100 ton
Cruise speed	483 km/h
Range	6,000 km
Freight rate	250% w.r.t. maritime [$]

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HUULC payload

800 Audi A4s

17 M1 tanks

5 Airbus A380s

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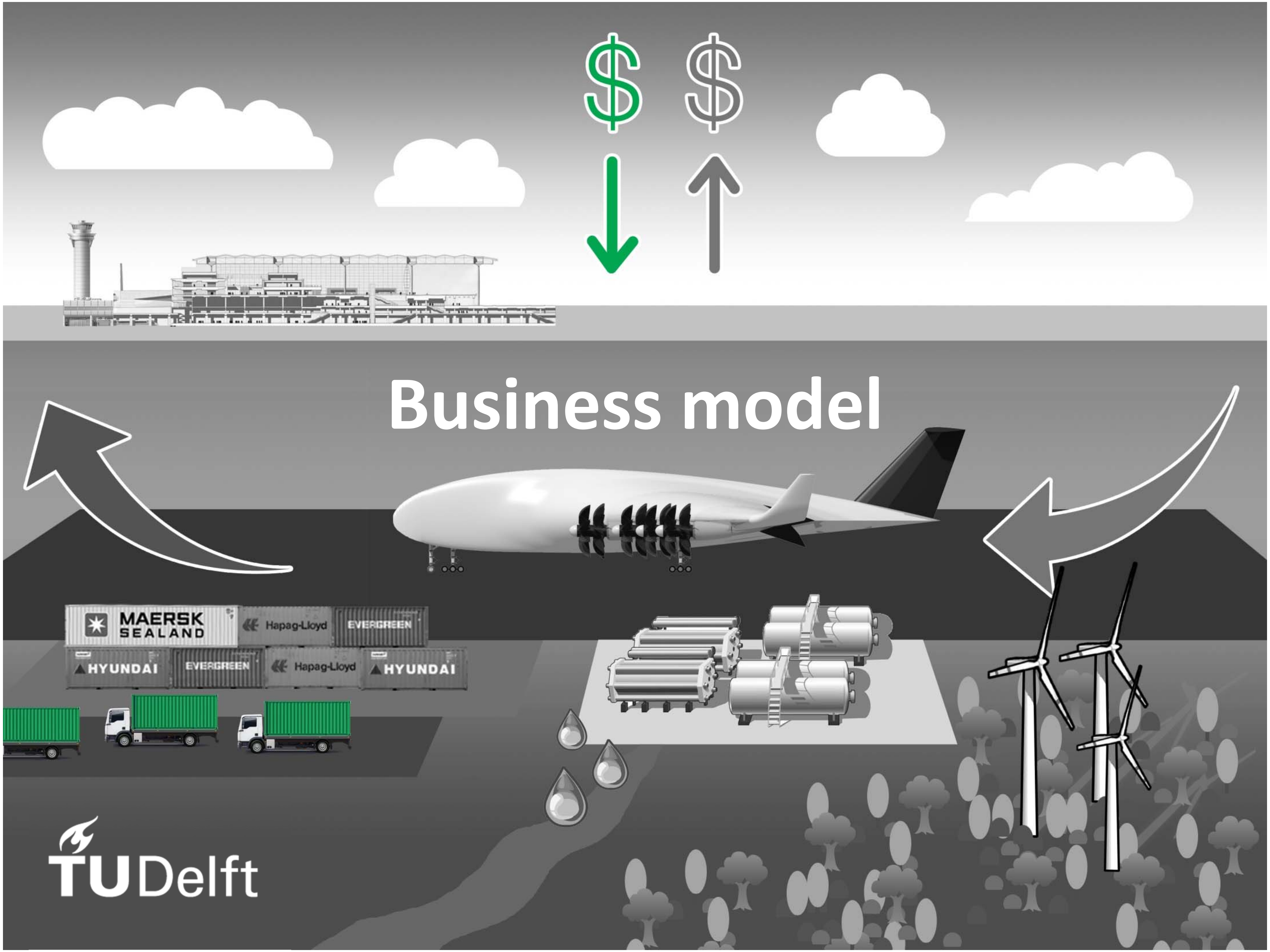
Business model
MAERSK SEALAND
Hapag-Lloyd
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HYUNDAI
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Hapag-Lloyd
HYUNDAI
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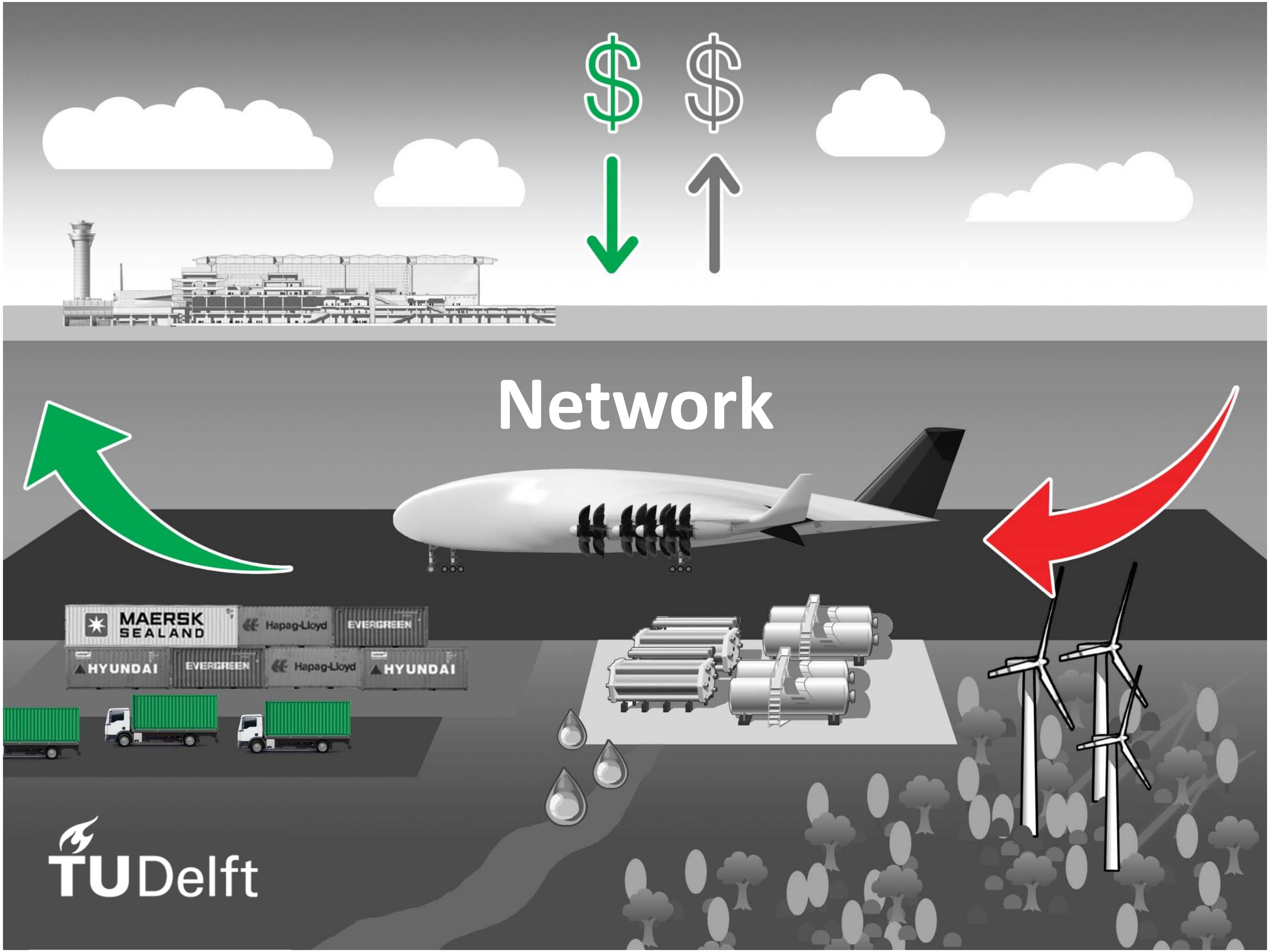

Network
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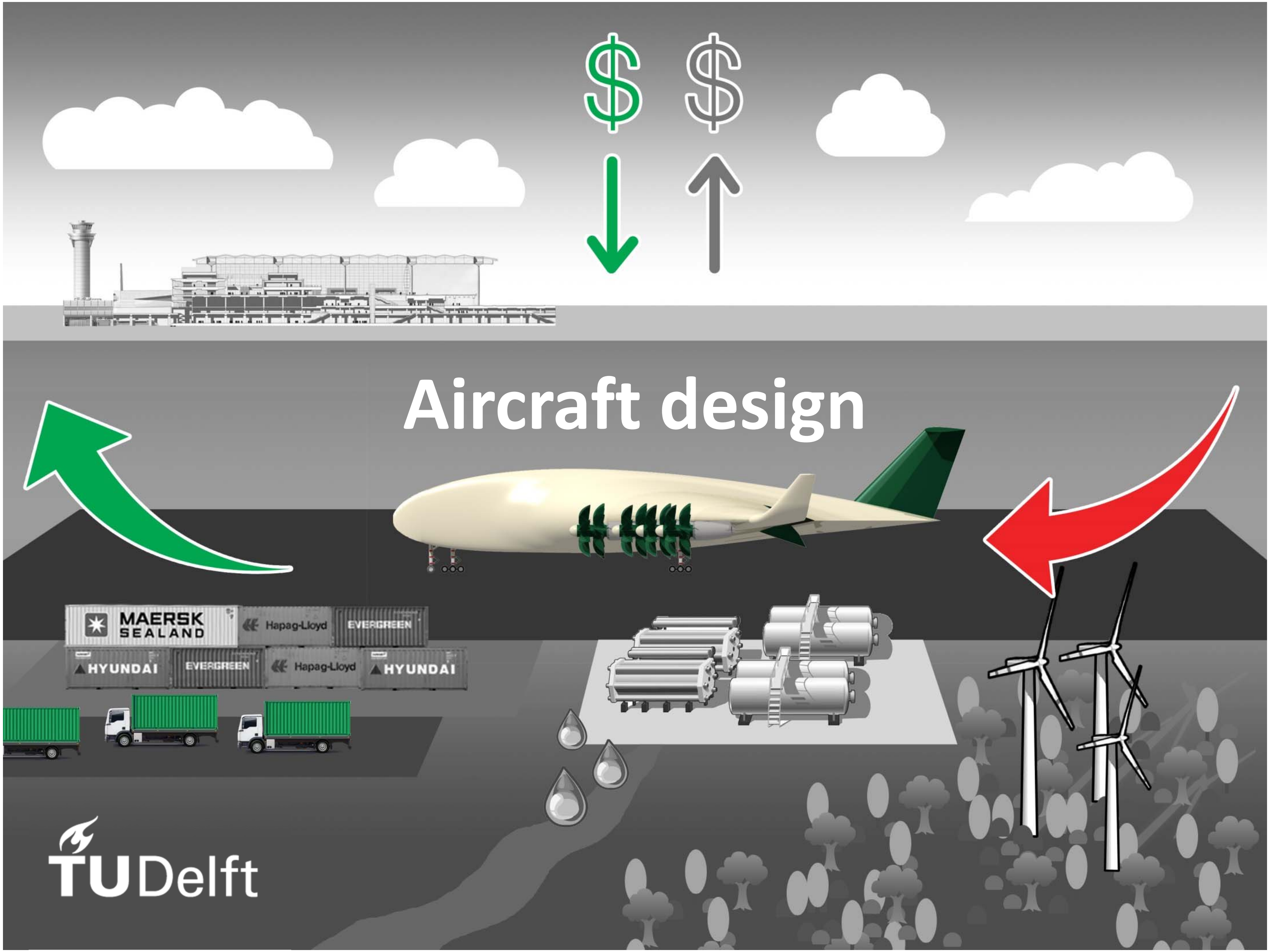
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Aircraft design
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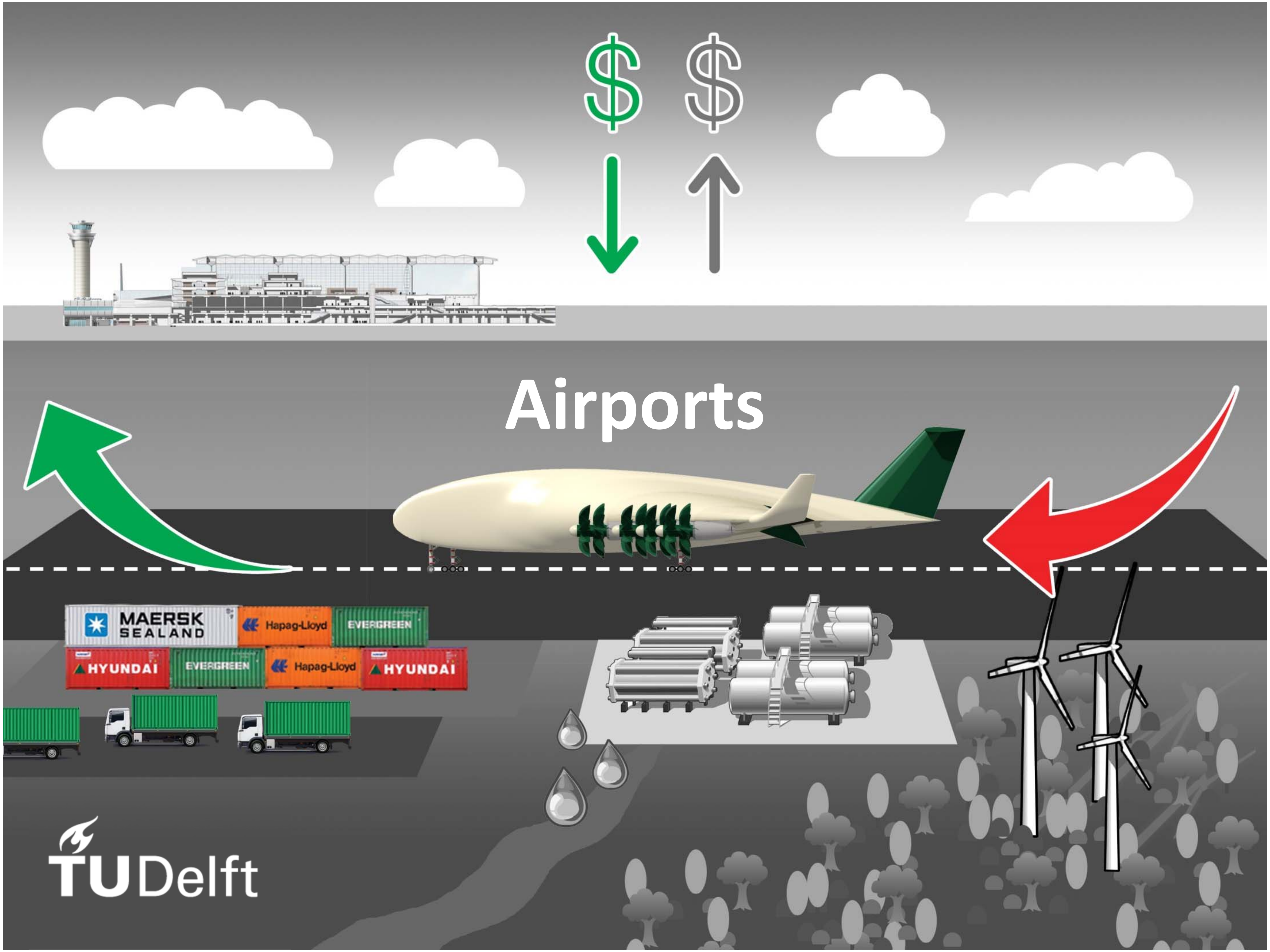

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Airports
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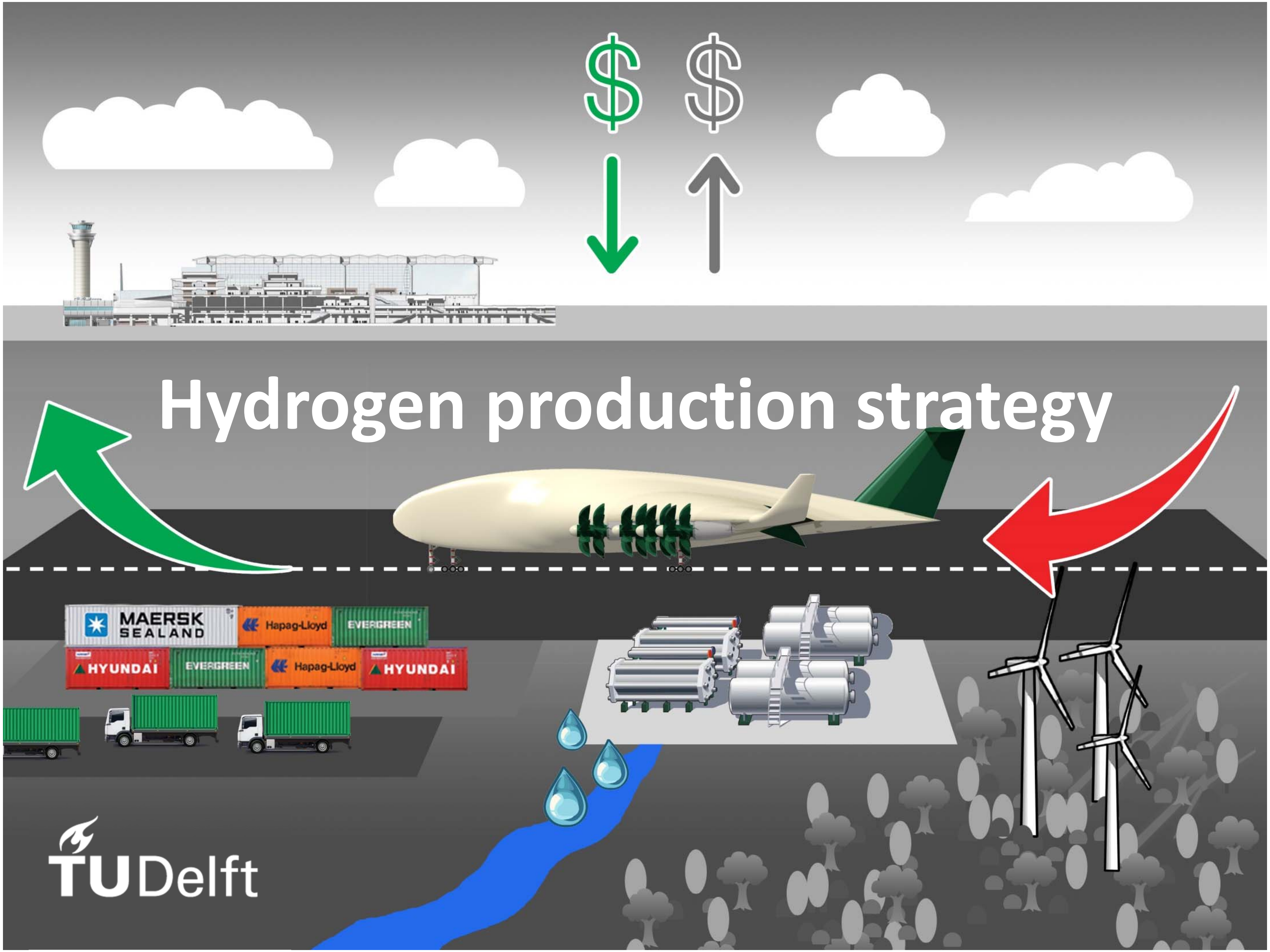
Hydrogen production strategy
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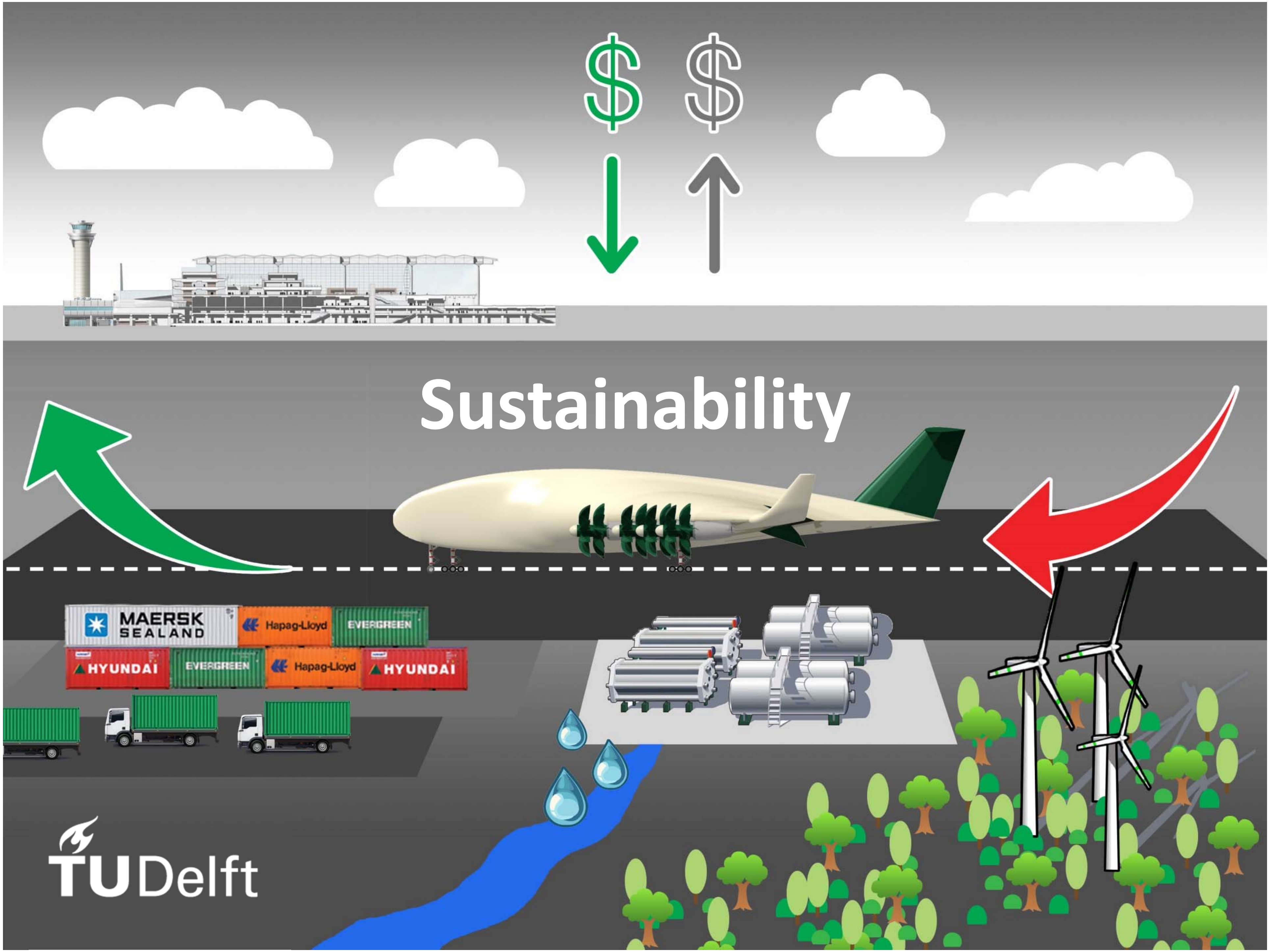

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Sustainability
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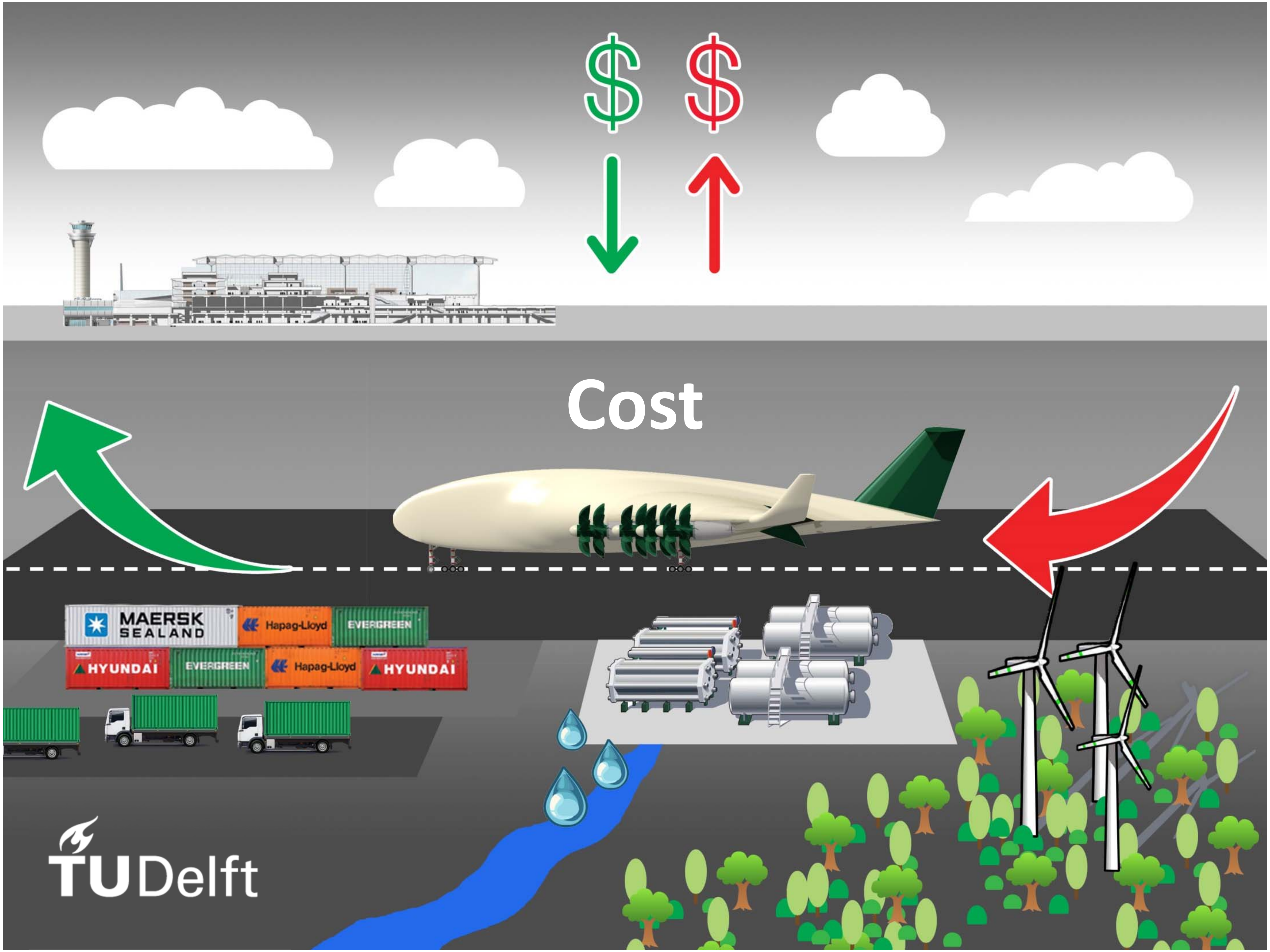

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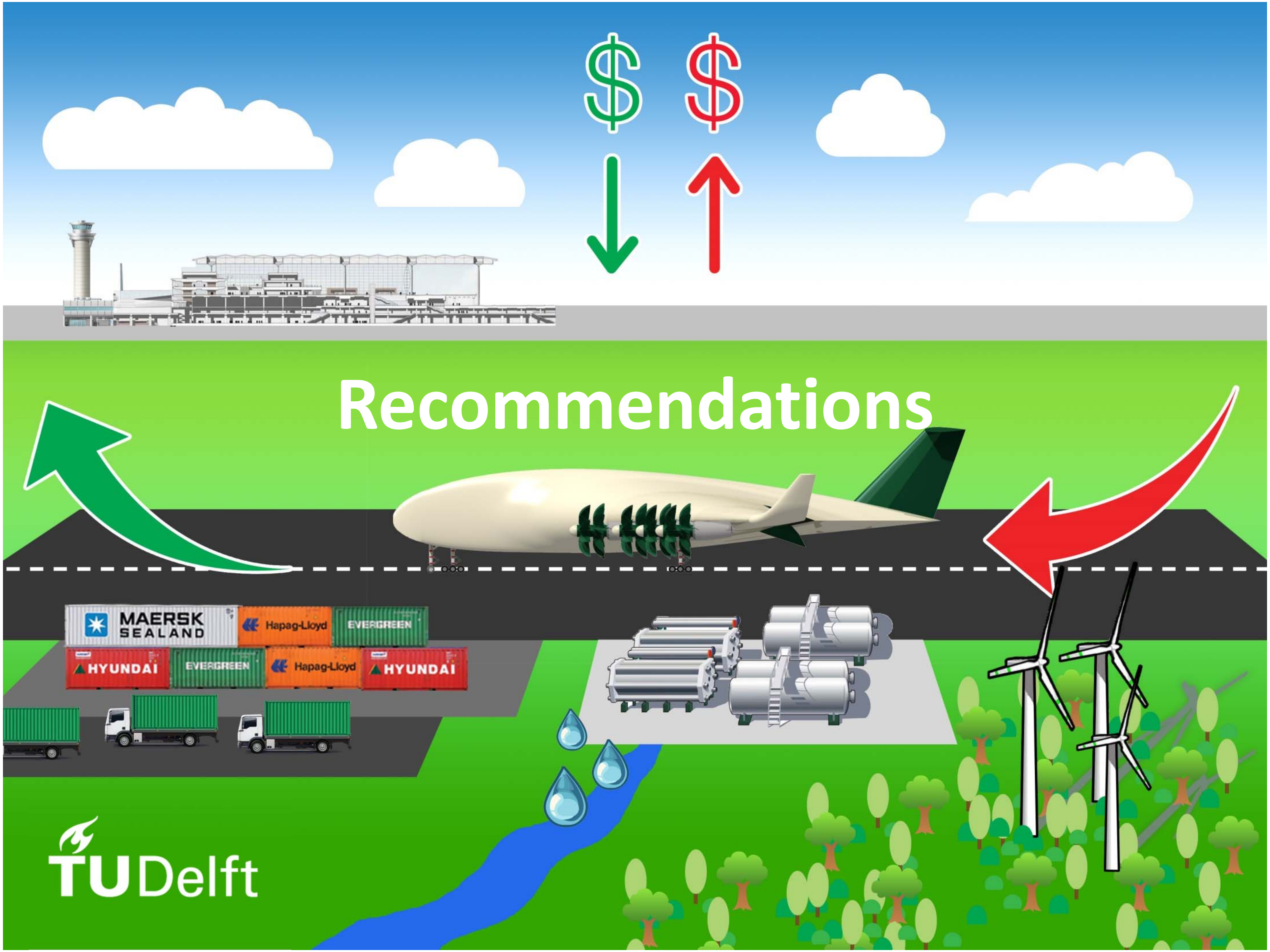
Recommendations
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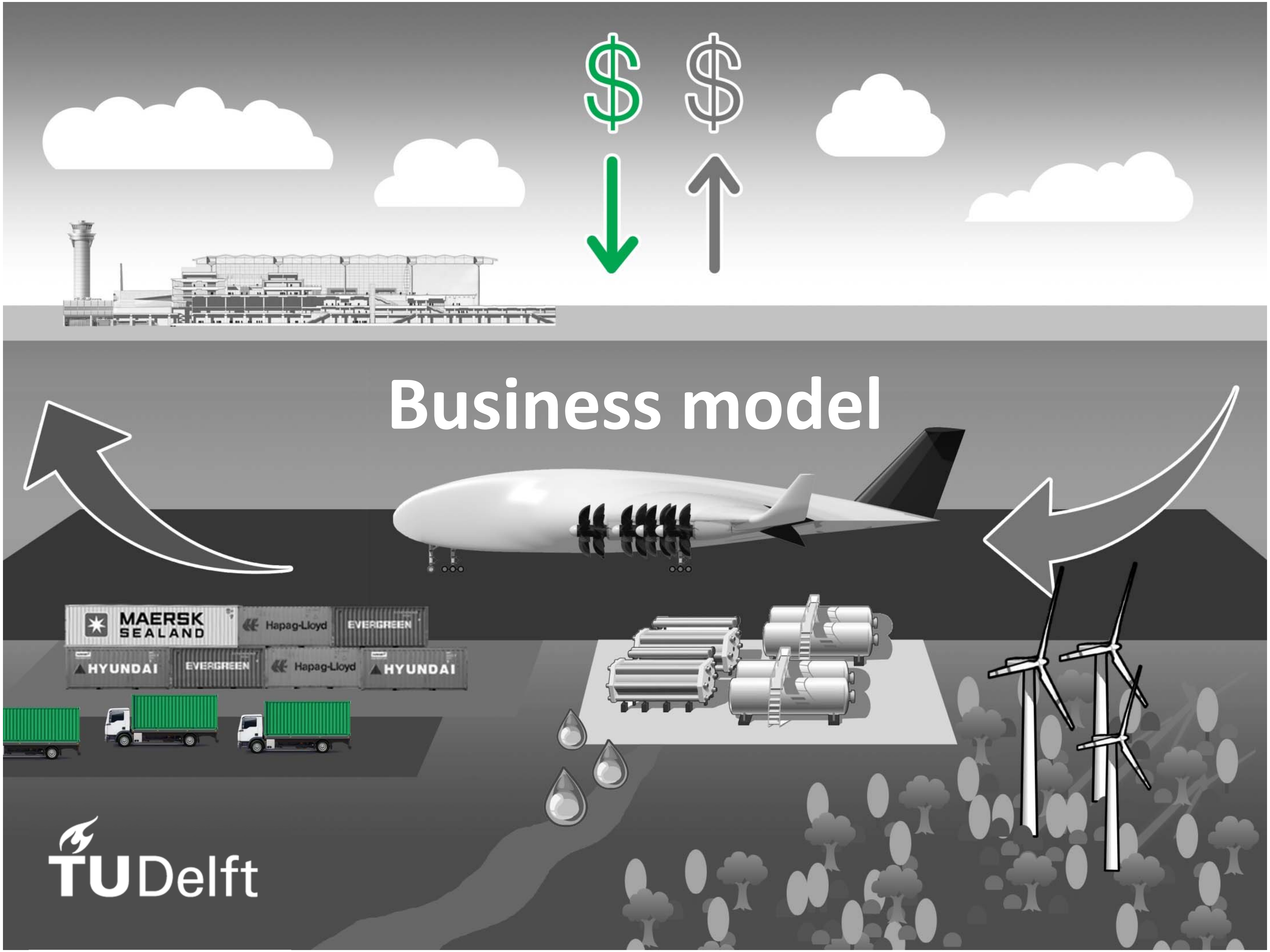
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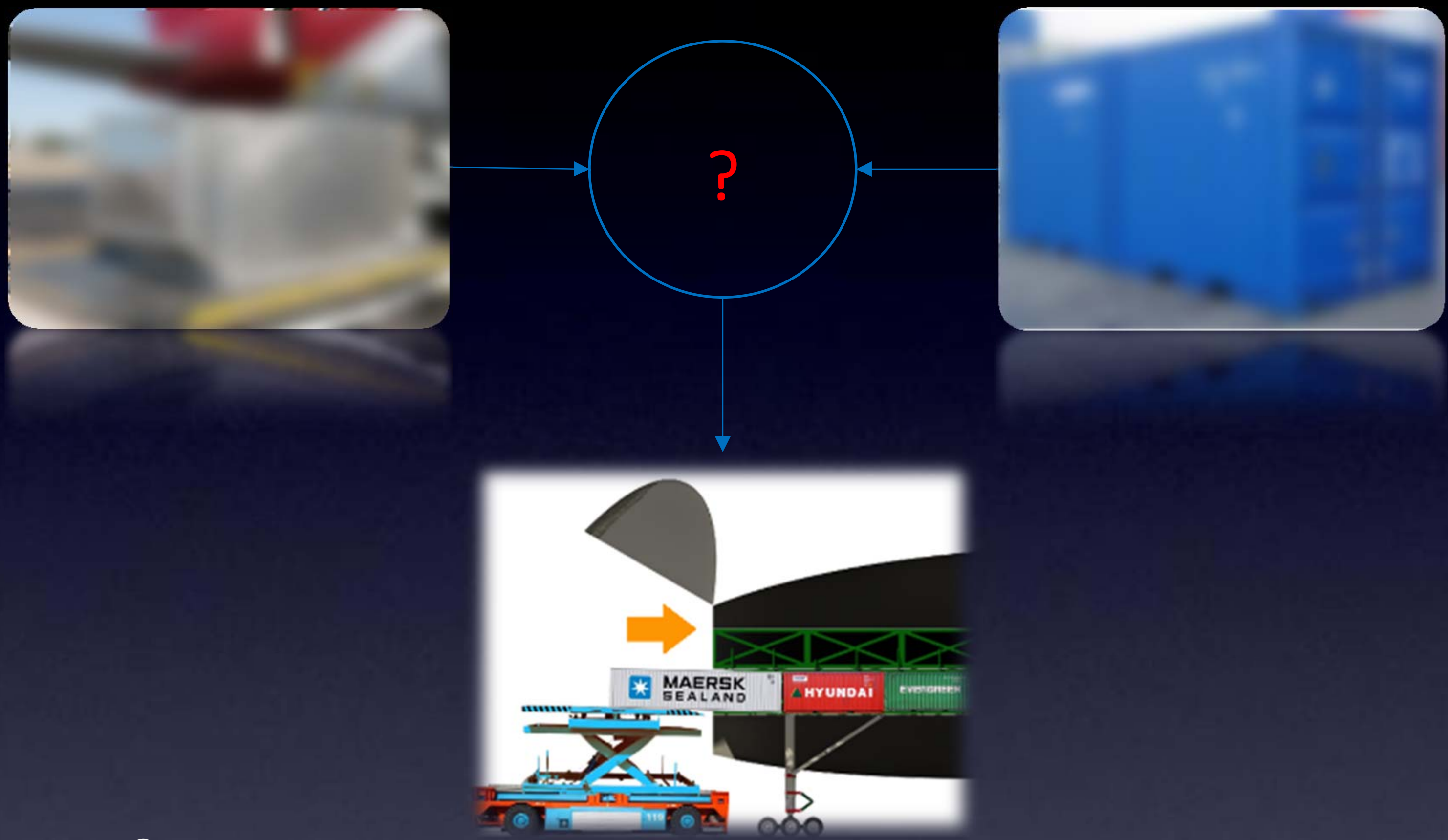
Business model



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Business model – Market share

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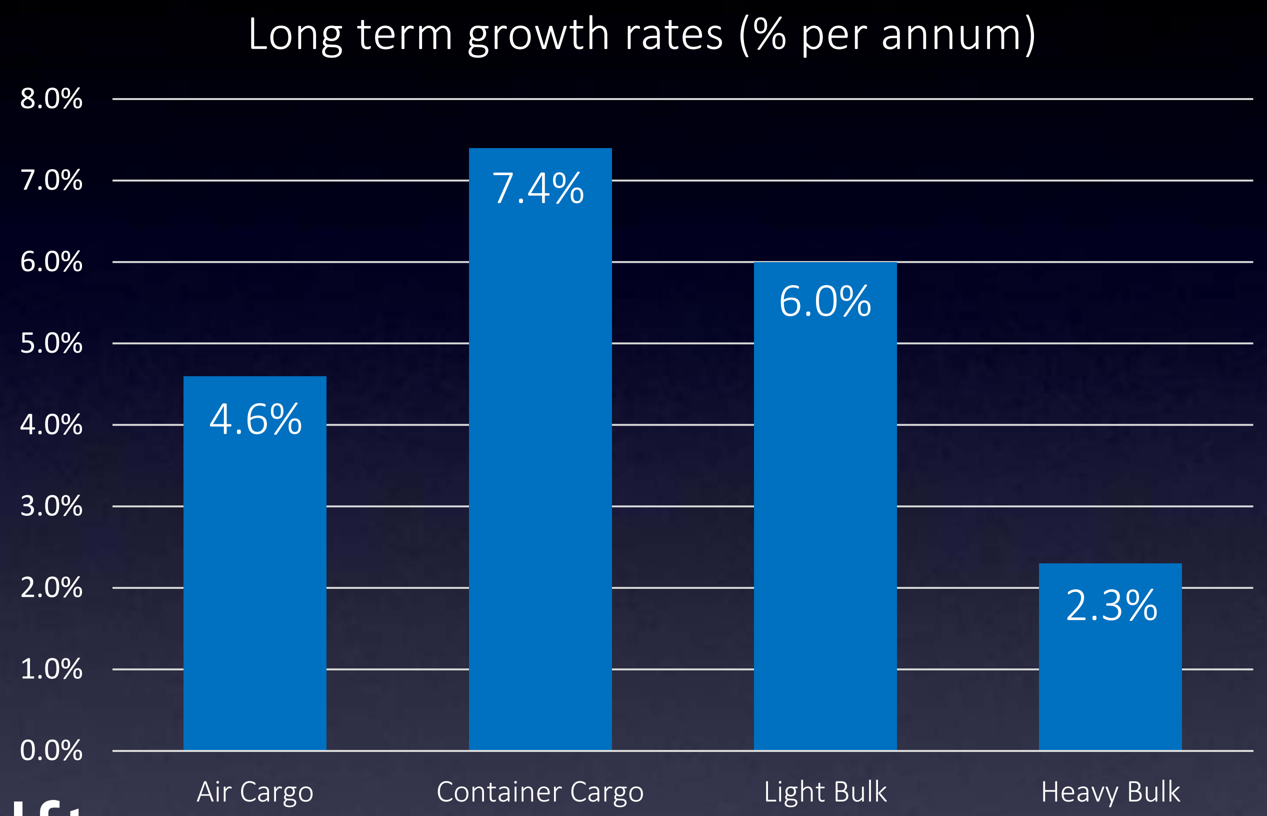
Business model – Market growth



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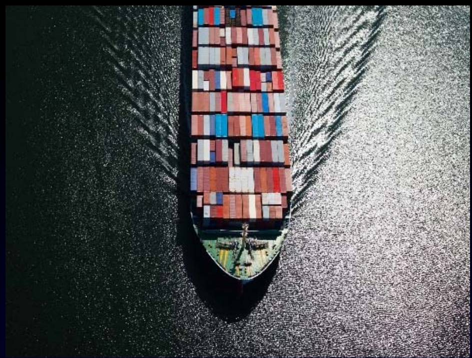
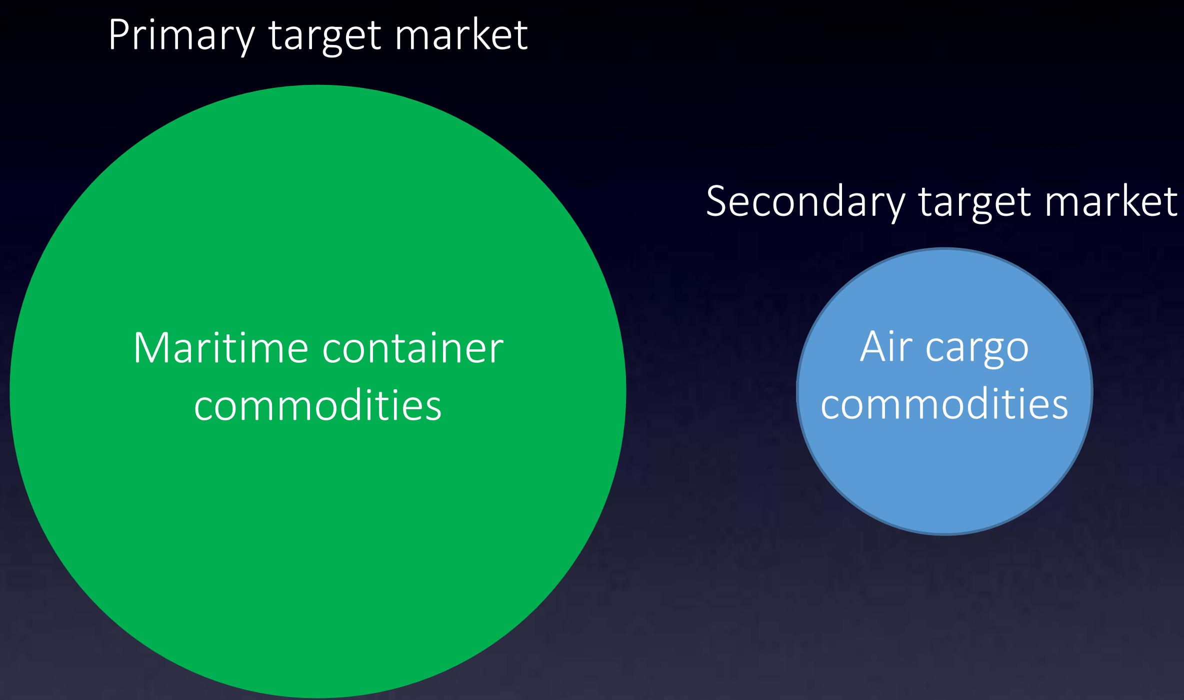
Business model – What cargo?



Low-value commodities

High-value commodities

Business model – Target markets



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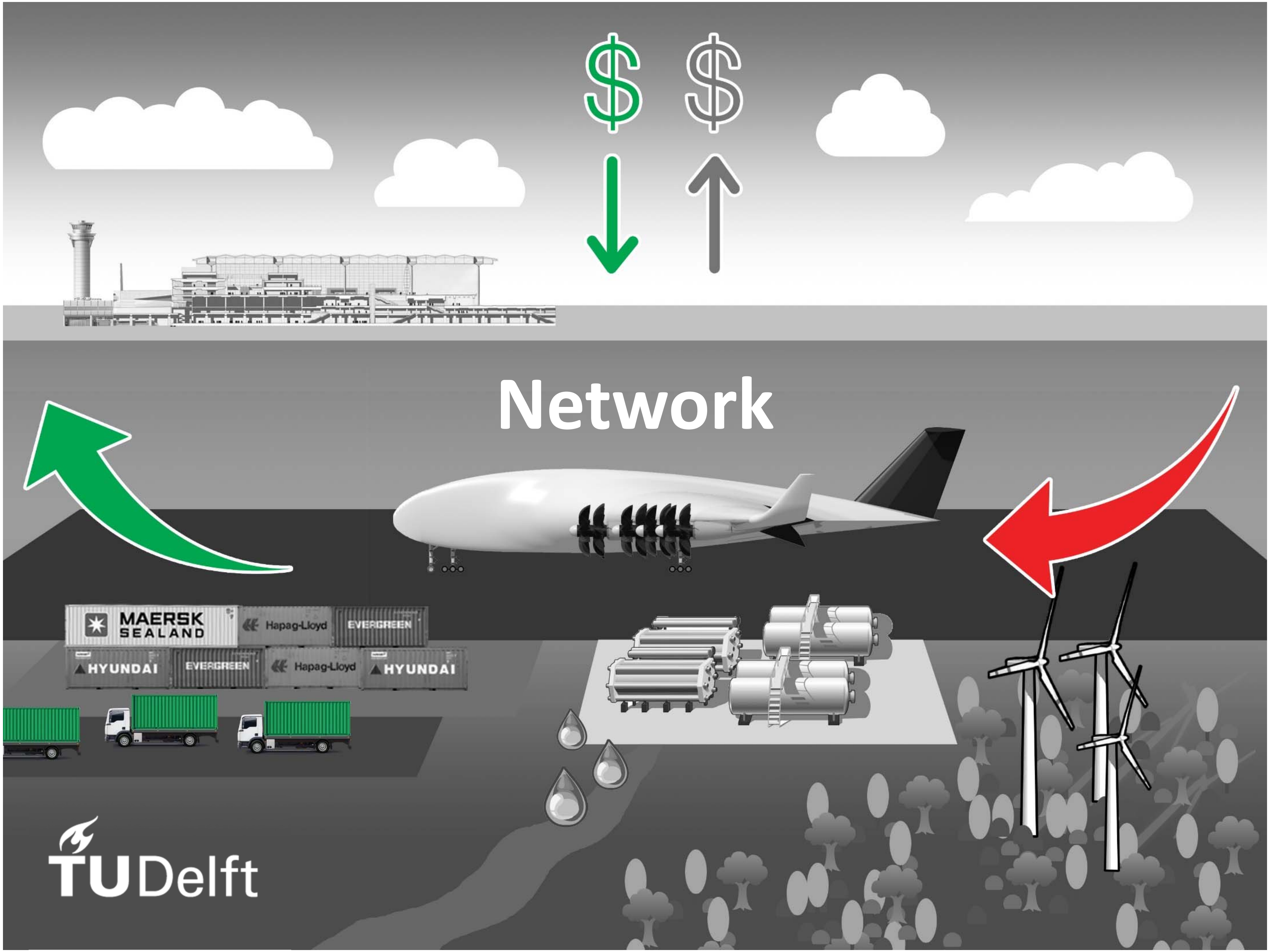

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Network

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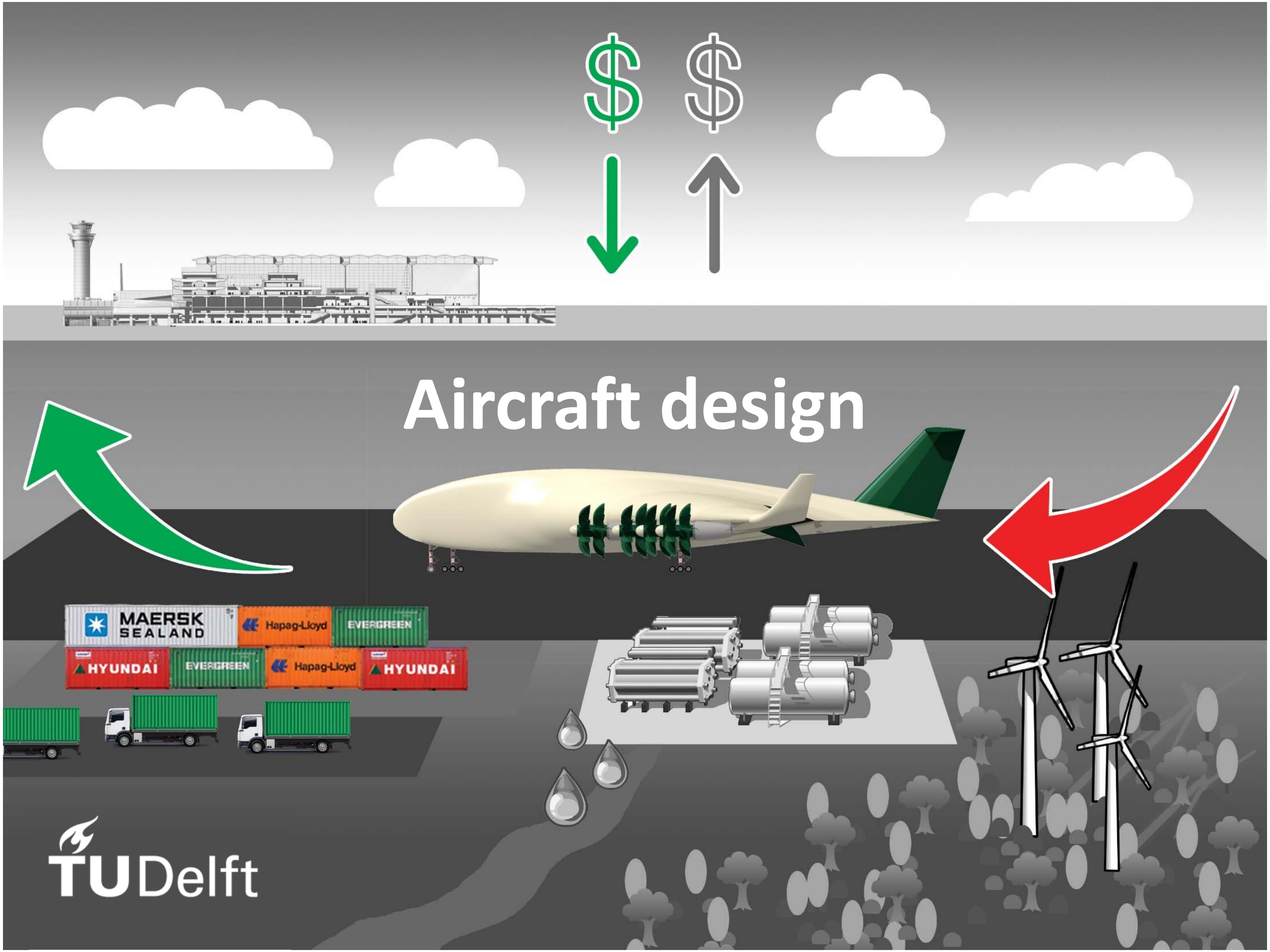
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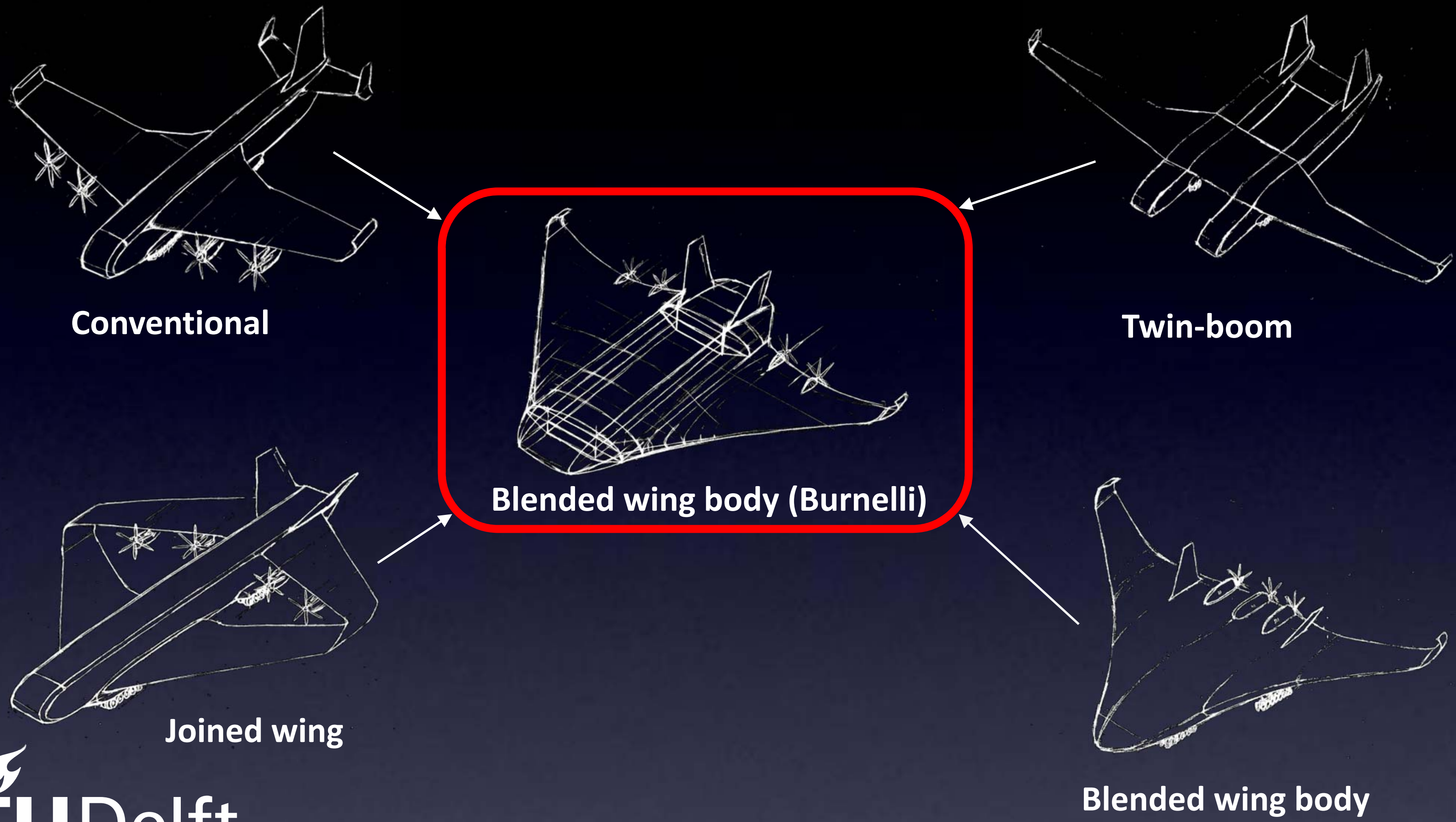
HUULC design – Configurations



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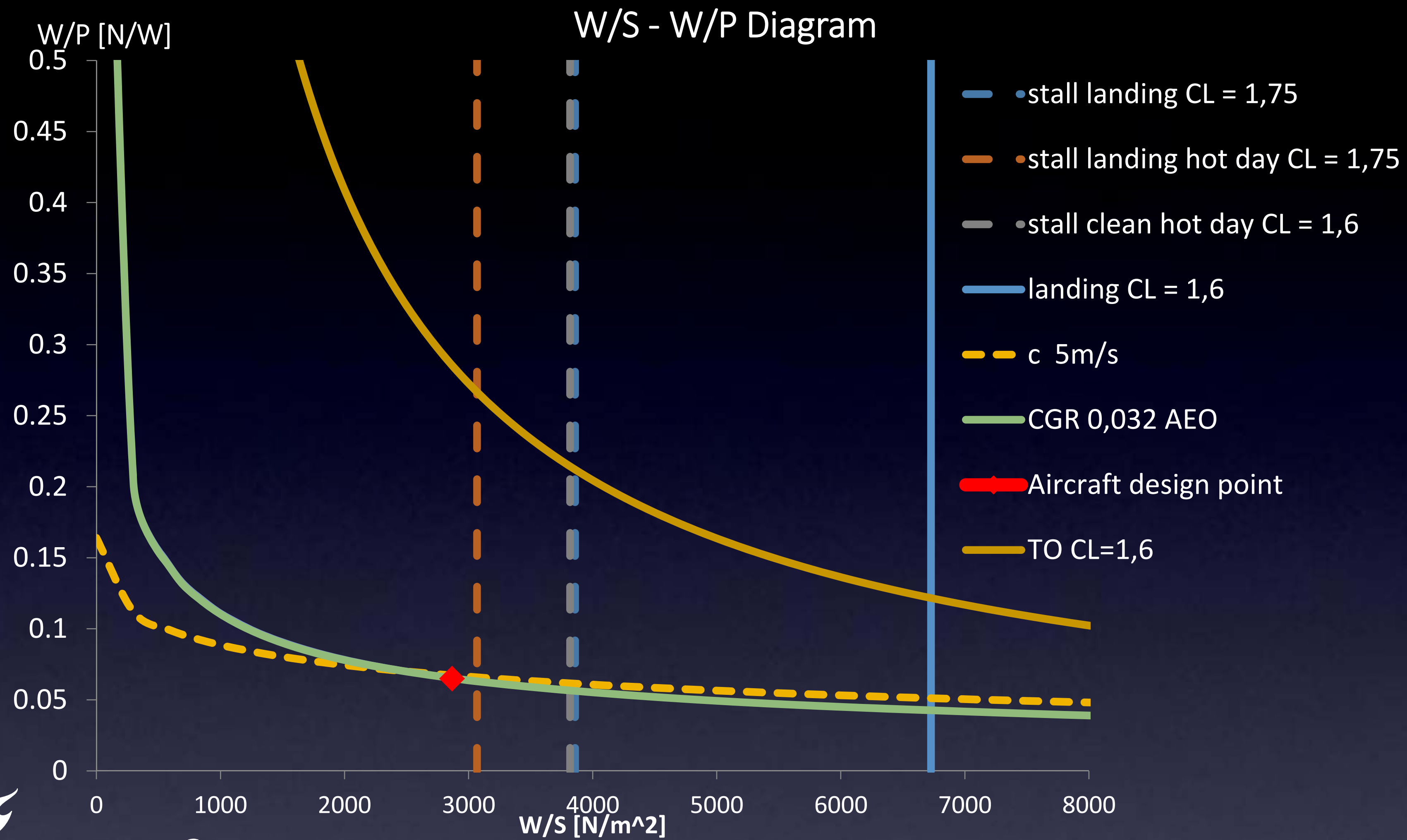
HUULC design – Design point



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HUULC design – Parameters

Parameter	HUULC Value
Wing loading [N/m^2]	2,866
Weight to power ratio [-]	0.065
Surface area [m^2]	7175
Wing span [m]	200
Power [MW]	316
Aspect ratio [-]	5.59
Oswald factor [-]	0.77
CLmax (clean) [-]	1.6
CLmax (takeoff) [-]	1.7
Clmax (landing) [-]	1.75

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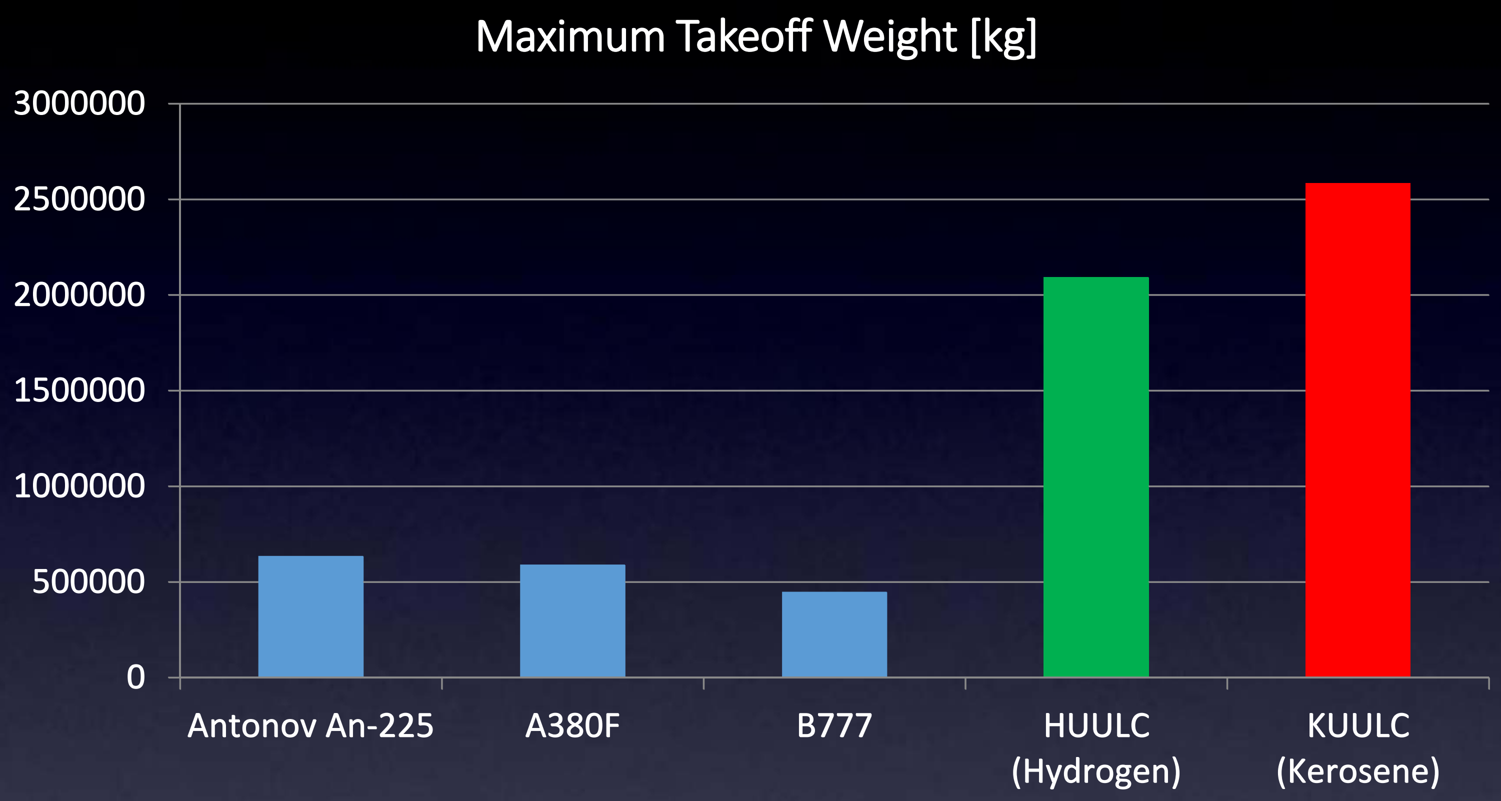
HUULC design – Preliminary sizing



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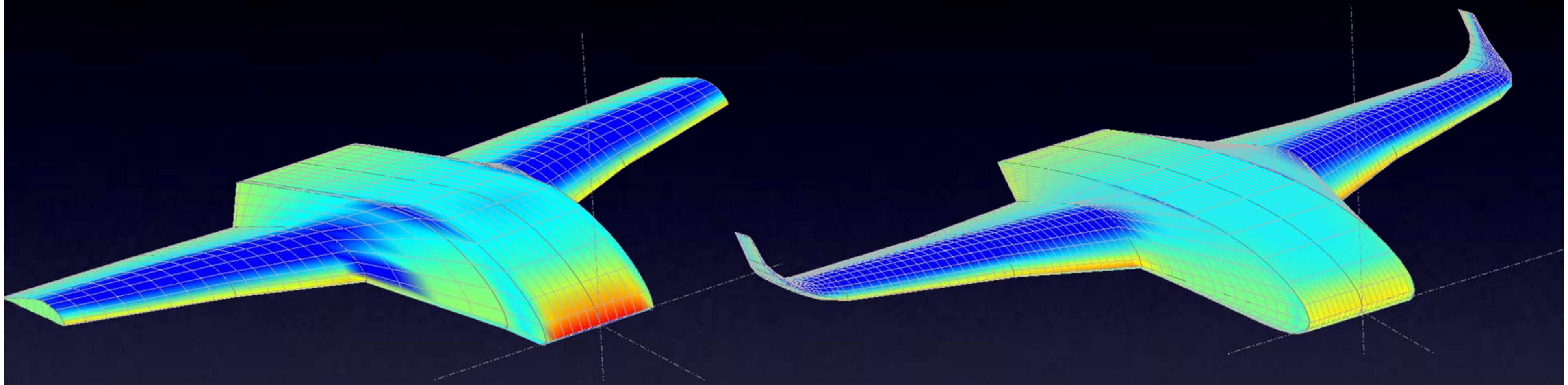
HUULC design – Aerodynamic analysis



Pressure contours

HUULC design – Aerodynamic analysis

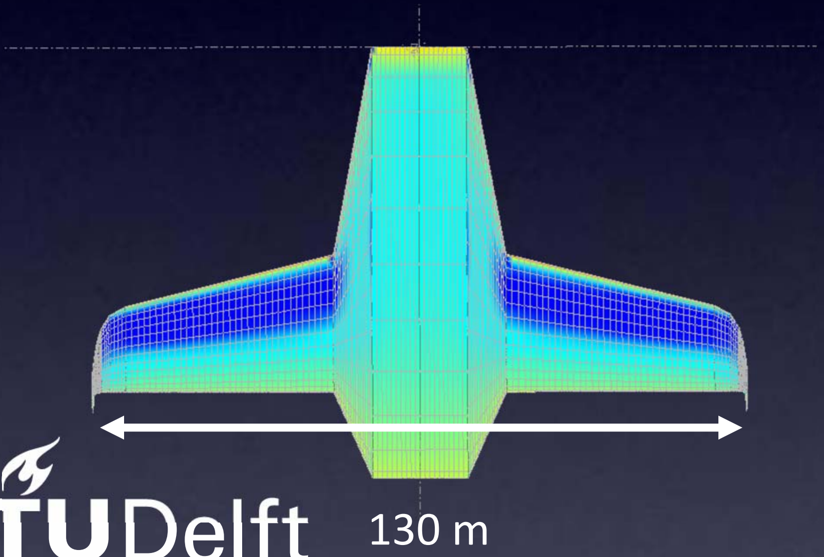
Span [m]	130
$C_{L,cruise}$ [-]	0.62
$C_{D,cruise}$ [-]	0.041
L/D [-]	15.1

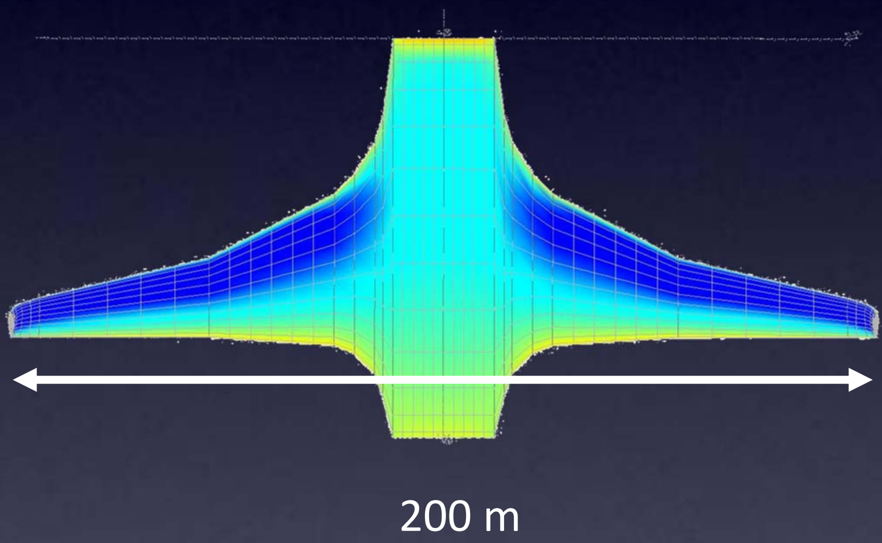
Lift coefficient is sufficient

However…

Drag coefficient leads to **46%** overshoot of hydrogen costs

Span [m]	200
$C_{L,cruise}$ [-]	0.62
$C_{D,cruise}$ [-]	0.022
L/D [-]	28.3





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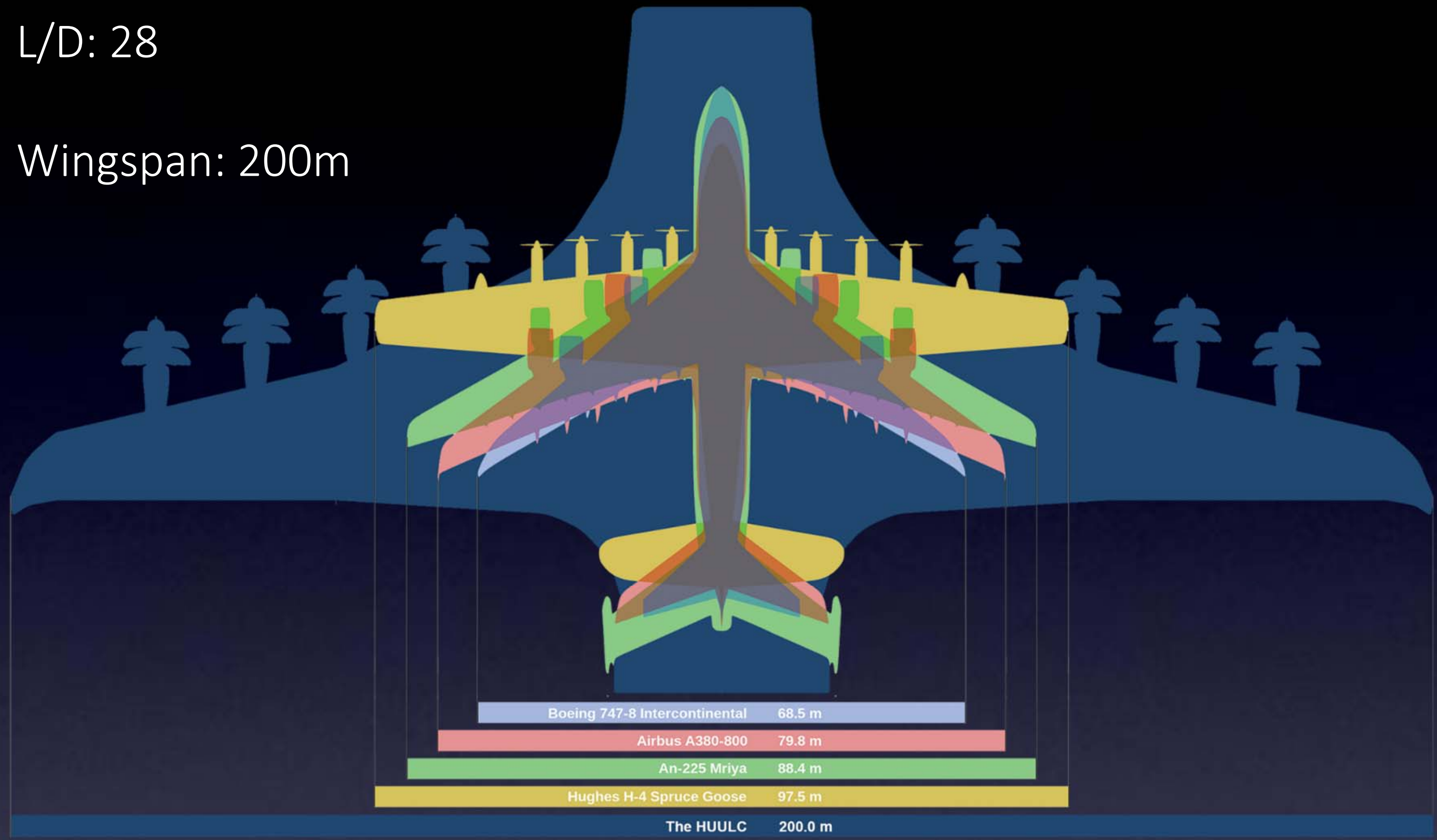
HUULC design – Aerodynamic analysis

- L/D: 28
- Wingspan: 200m



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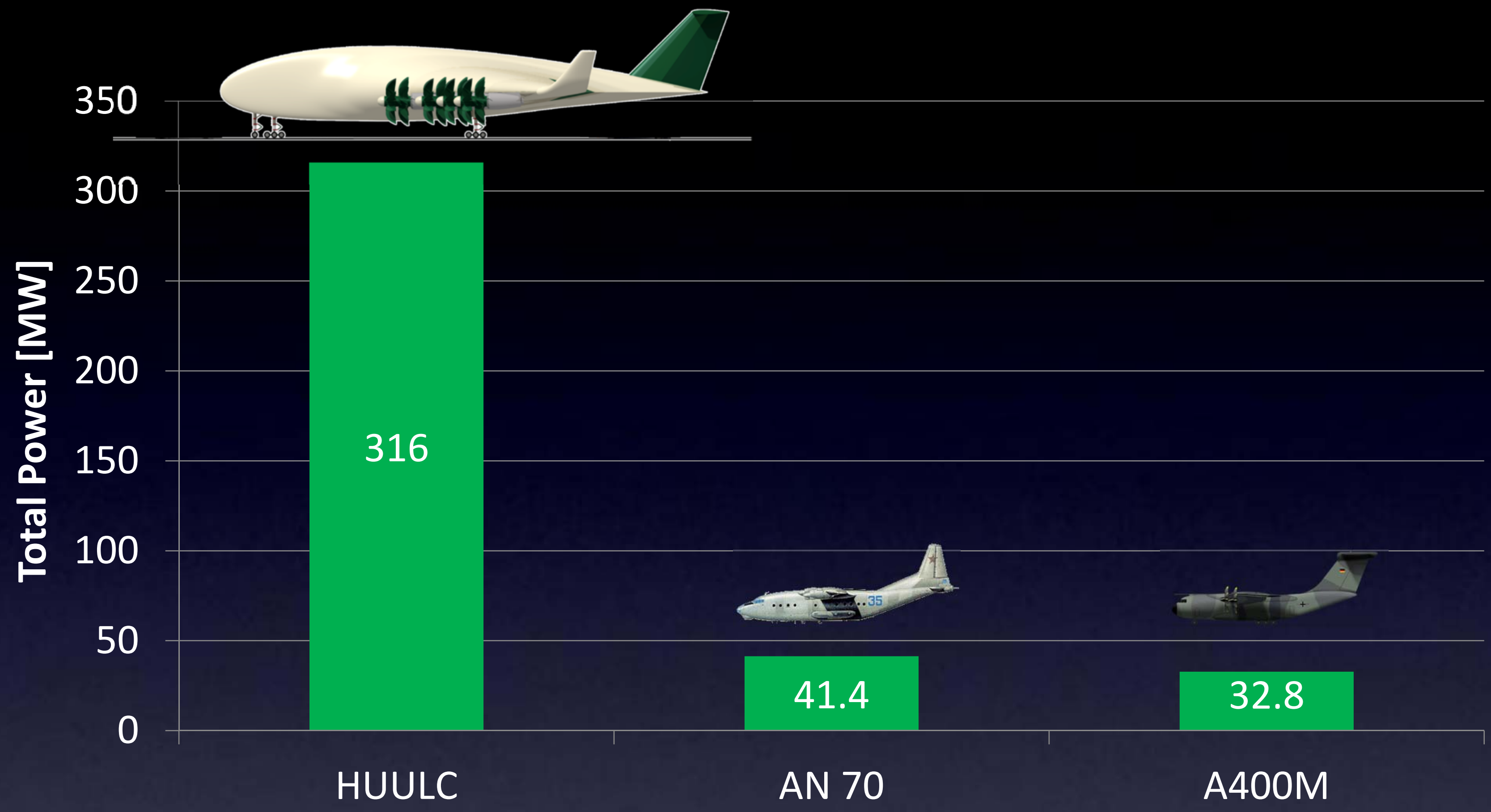
HUULC design – Propulsion



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HUULC design – Propulsion

Contra-rotating propfan

- Capture of swirl flow
- Up to 35% fuel savings

Noise

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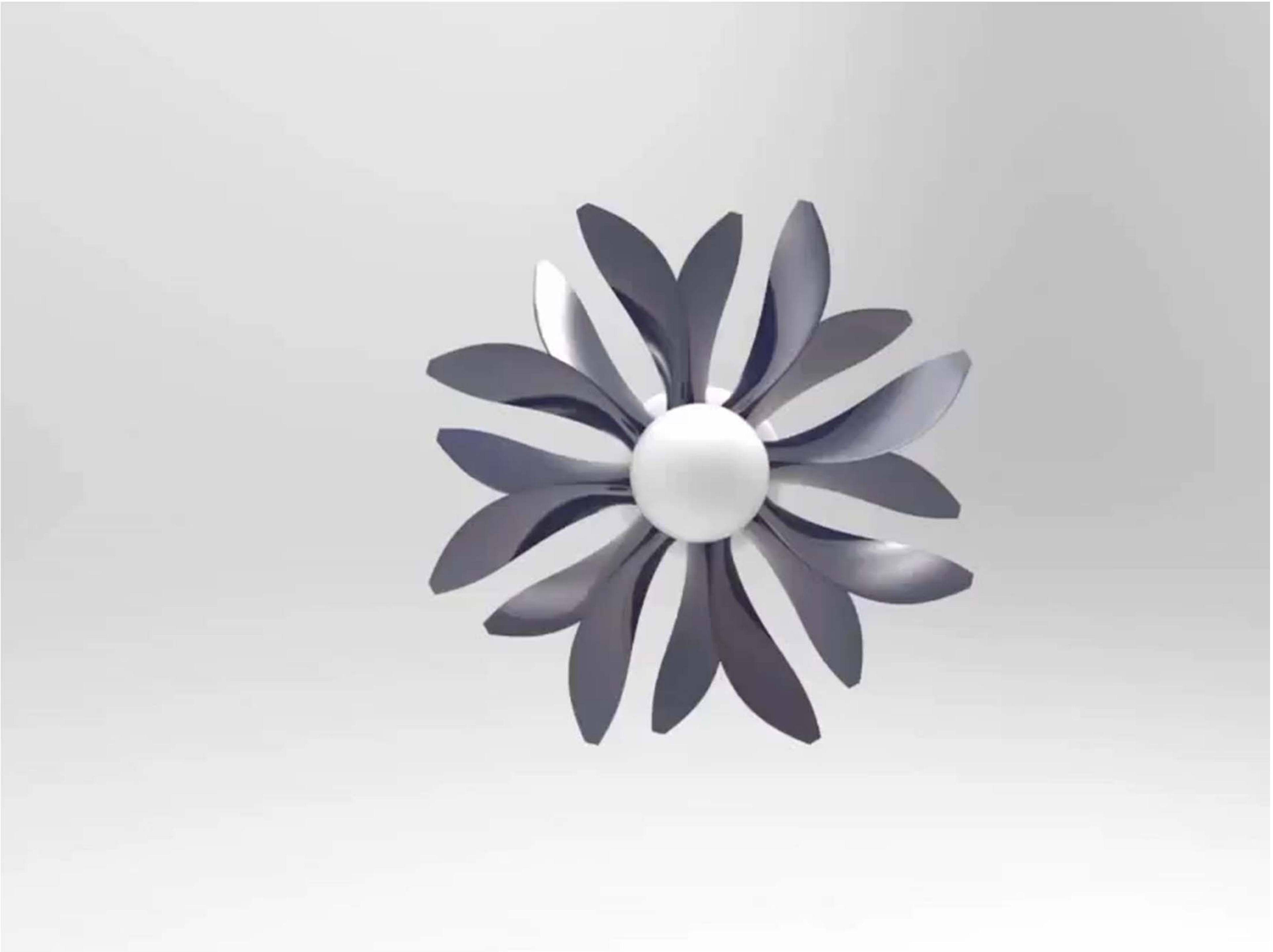

HUULC design – Propulsion

Challenges

- Fuel Efficiency is ESSENTIAL
- Flight path 2050
- Reduce noise generated by contra-rotating technology

NACRE , JTI , DREAM

Reported progress in noise reduction

HUULC design – Vertical tail design

- Tail volume coefficient method yields vertical tail area of 398 m^2
- Need to reduce vertical tail size for aeroelastic effects and hangar storage

↓

Two tails

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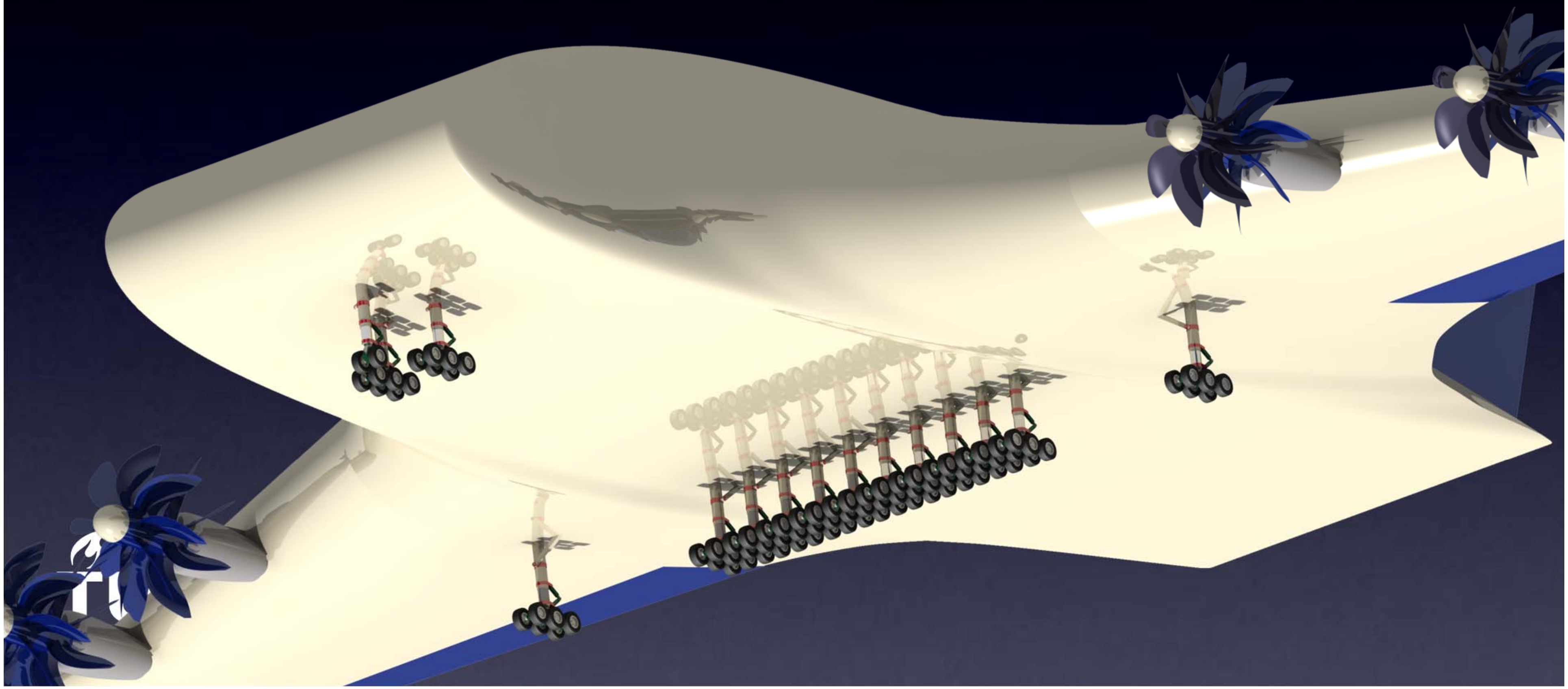
HUULC design – Vertical tail design

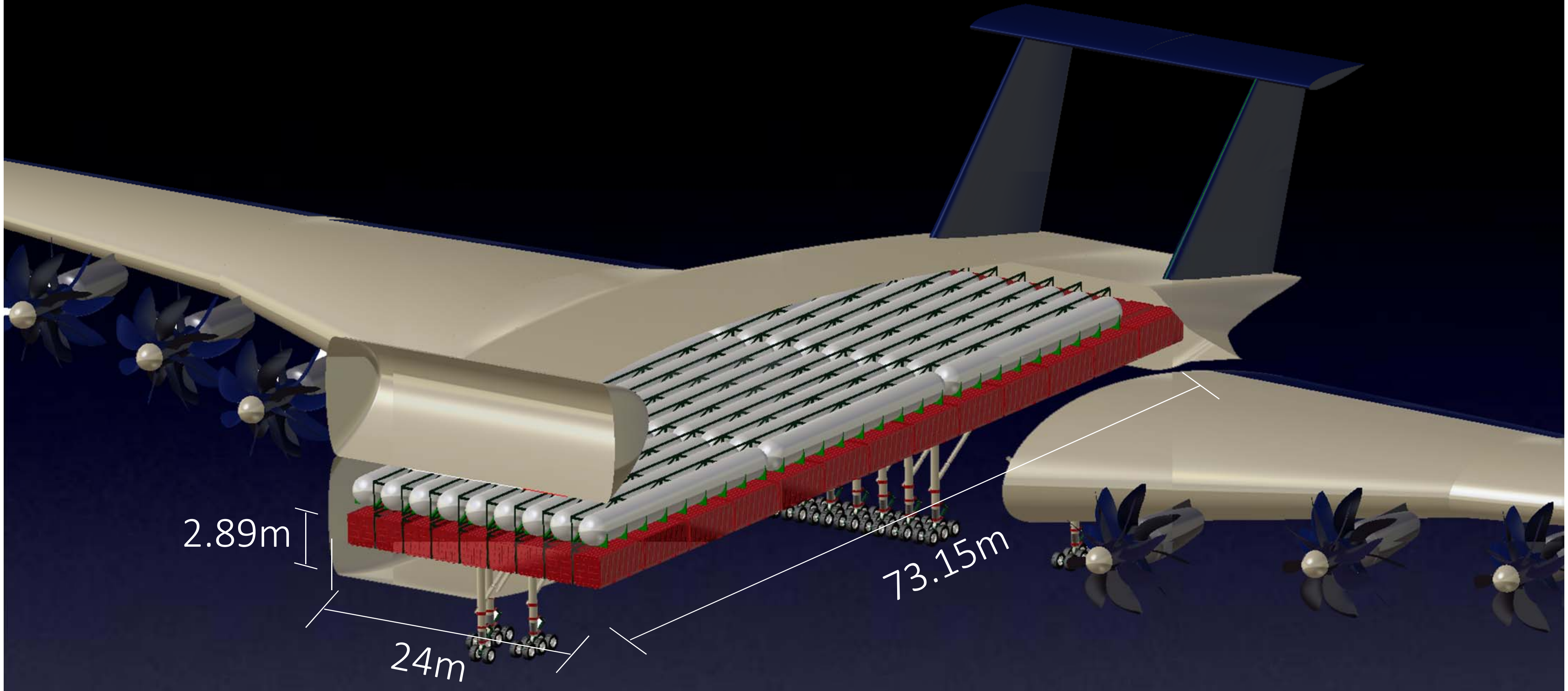
HUULC design – Landing gear

Number of tires: 86 (14 nose, 72 main)

Max load per tire: 28,890 kg



HUULC design – Payload bay



9 x 12 TEU spaces
2,153m³ volume

9 x 3 cryo-hydrogen fuel tanks
5,074m³ volume

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HUULC design – Fuel tanks

- Trade-off between high pressure or cryogenic storage
- Cryogenic storage allows for lightest hydrogen tank
- Temperature of 25K with 0.4Mpa pressure
- 239m^3 per tank

HUULC design – Unmanned

Operational benefits

- No flight crews
  - One single pilot controlling multiple HUULCs
  - Resulting in savings on pilot salary is 2.44% of the **ENTIRE** Operations and Maintenance costs
- No scheduling issues
  - Avoidance of cargo denial
  - Only empty return flights are for maintenance

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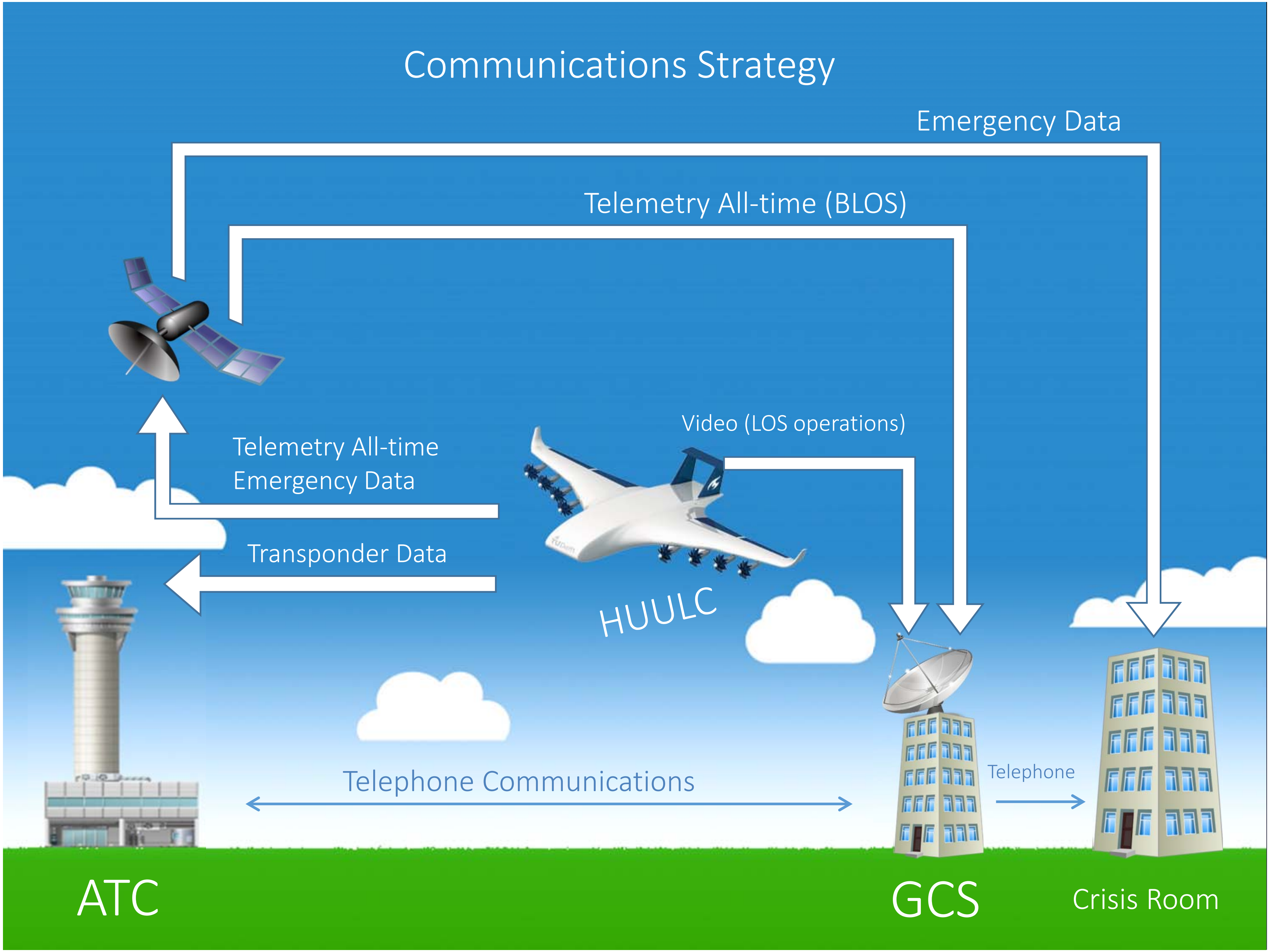


Communications Strategy
Emergency Data
Telemetry All-time (BLOS)
Video (LOS operations)
Telemetry All-time
Emergency Data
Transponder Data
HUULC
Telephone Communications
Telephone
ATC
GCS
Crisis Room

HUULC design – Containers

Purpose-built lightweight container

- Composite materials
- 78% weight reduction compared to standard TEU container

HUULC design – Containers

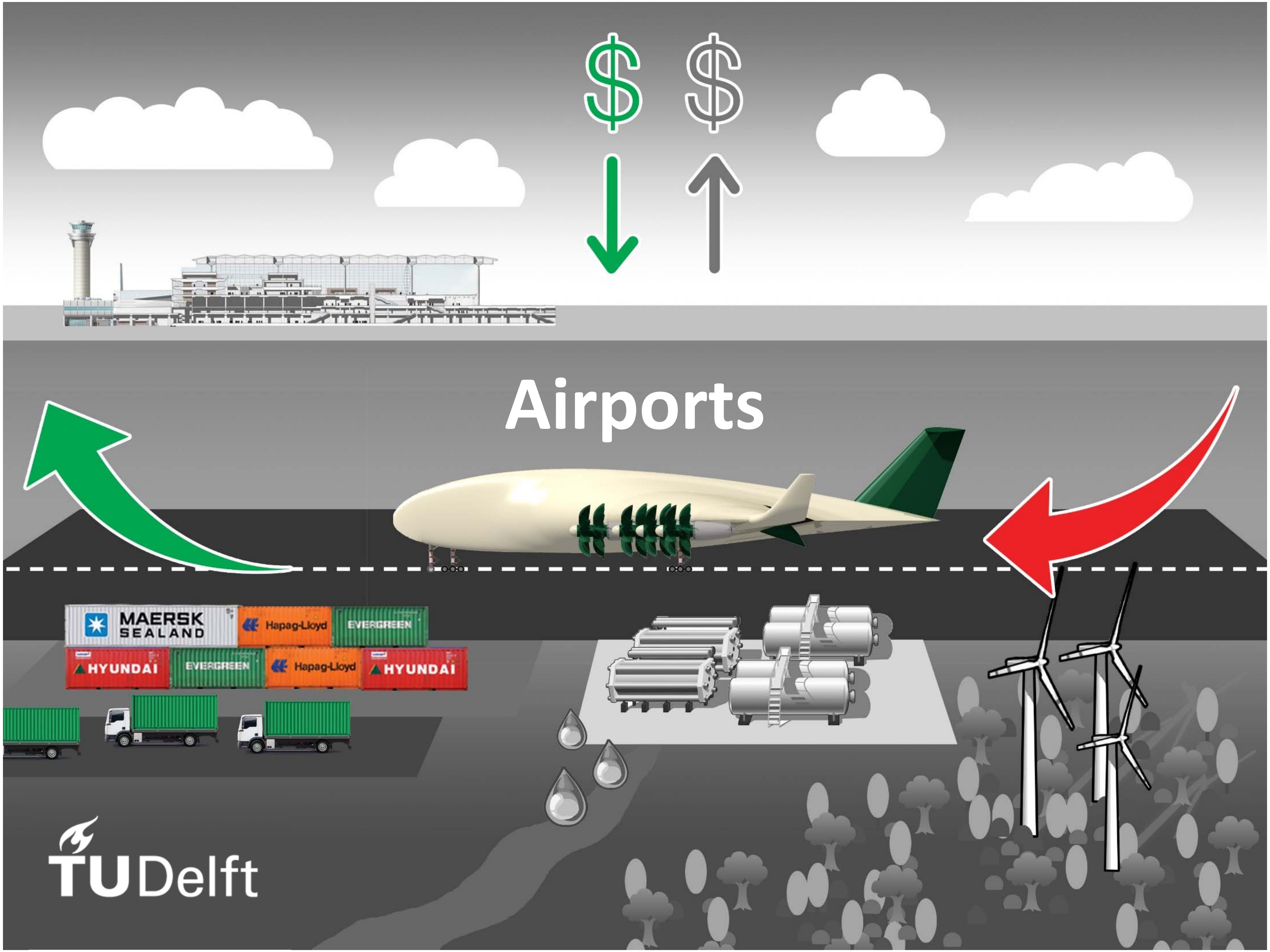
Transportable goods:

- Lack of pressure:


- Perishable temperature:

?

Reefers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Airports
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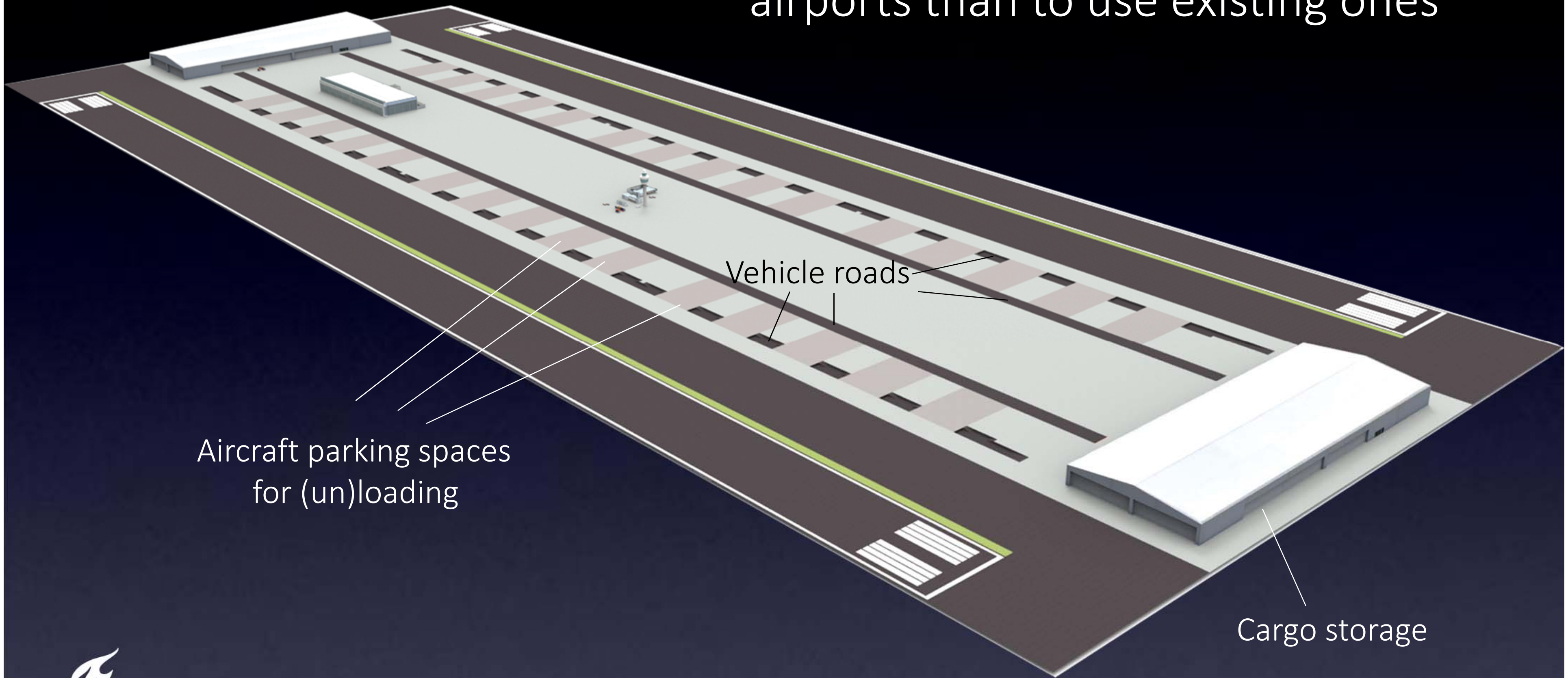
Airport design

Issues with existing airports:

- Airport fees
- Wingspan limits
- Congestion

Airport design

30% less expensive to build 6 airports than to use existing ones



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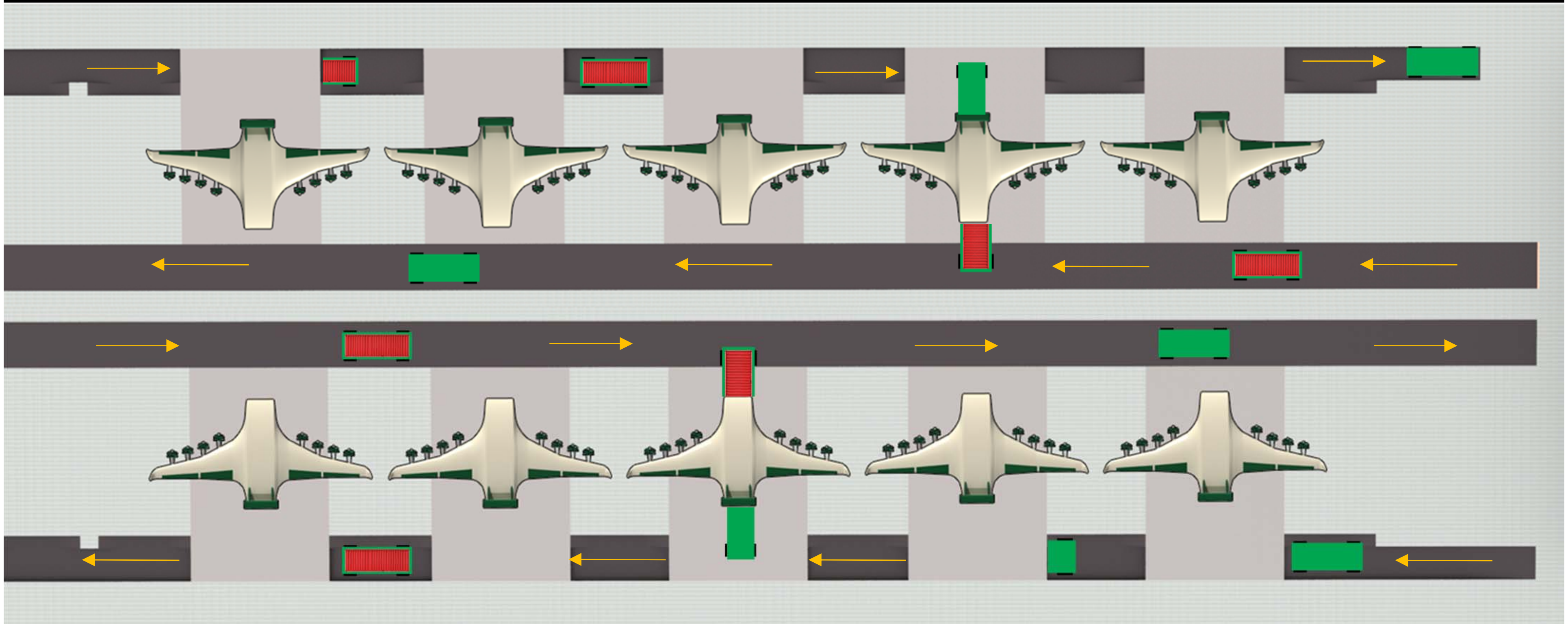
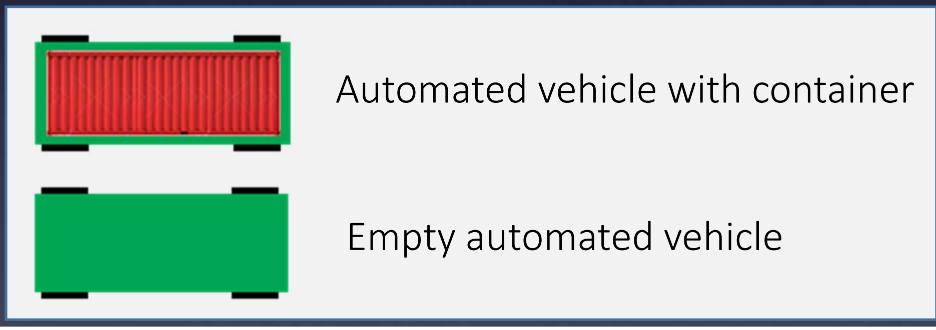
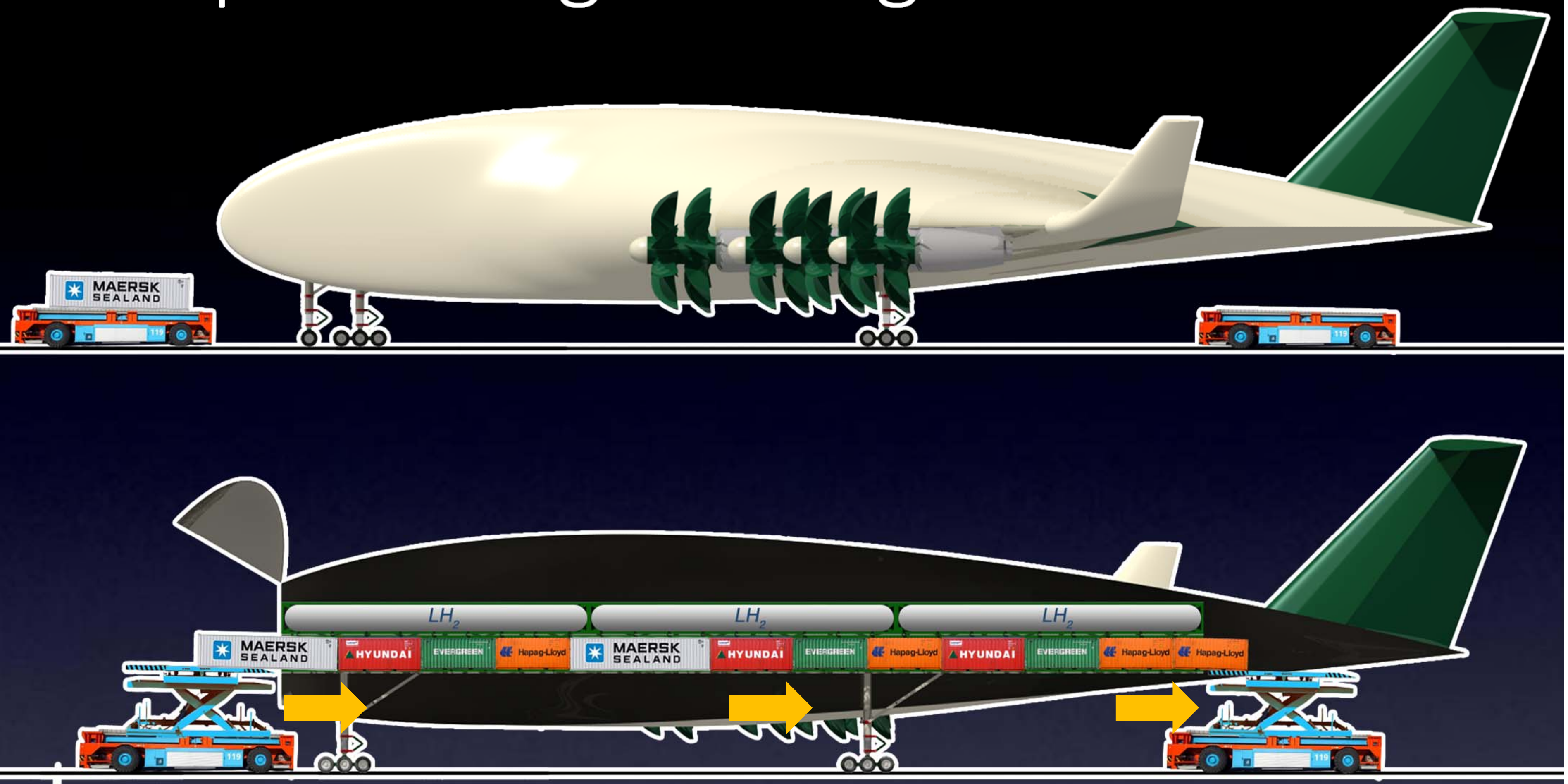
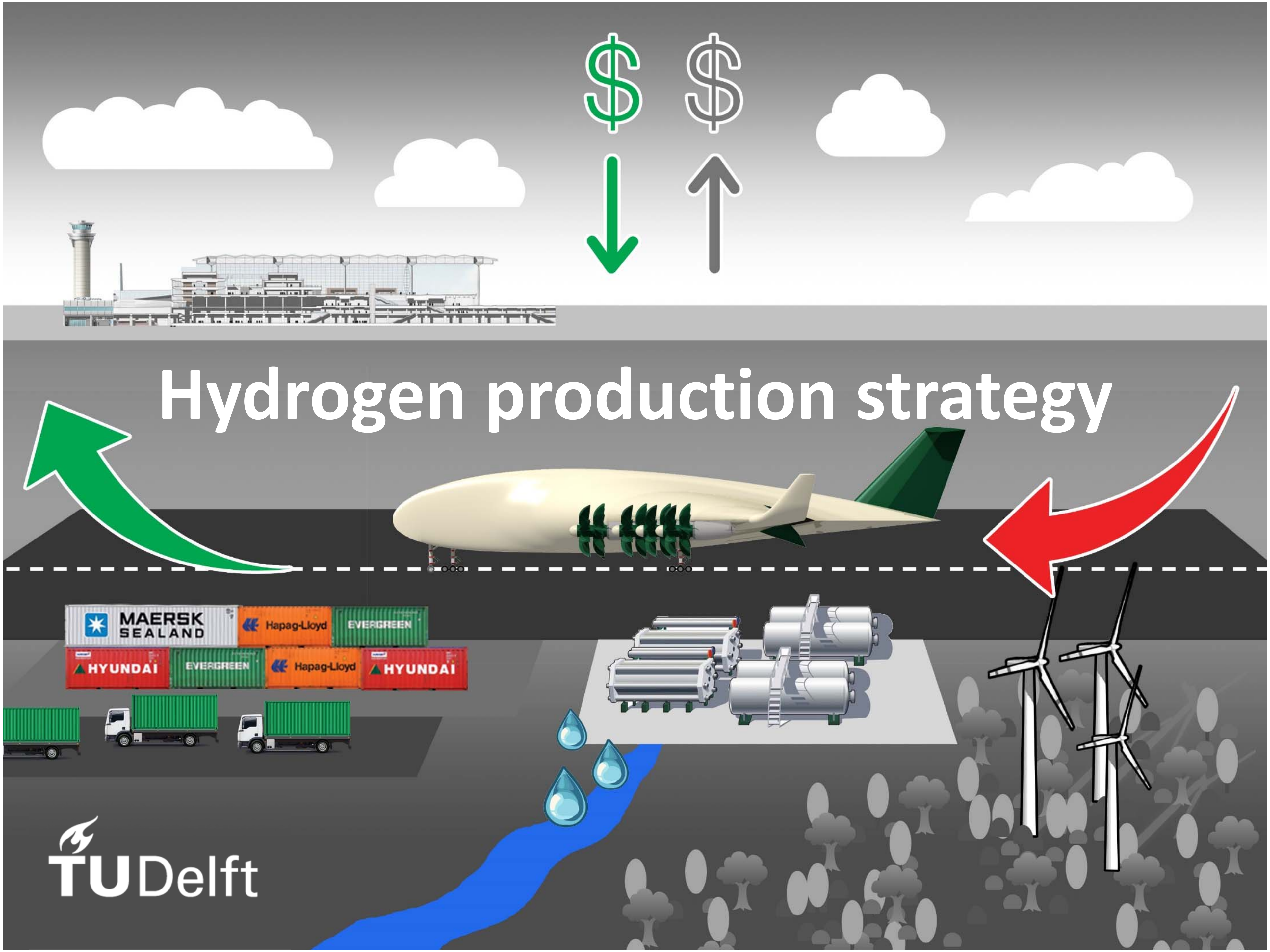
Airport design – CargoFlo





Airport design – CargoFlo




Hydrogen production strategy
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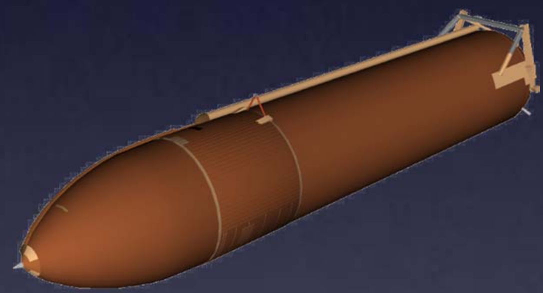
Hydrogen production strategy

For entire fleet: 36.6 million kg LH2 per day

58 space shuttle main boosters



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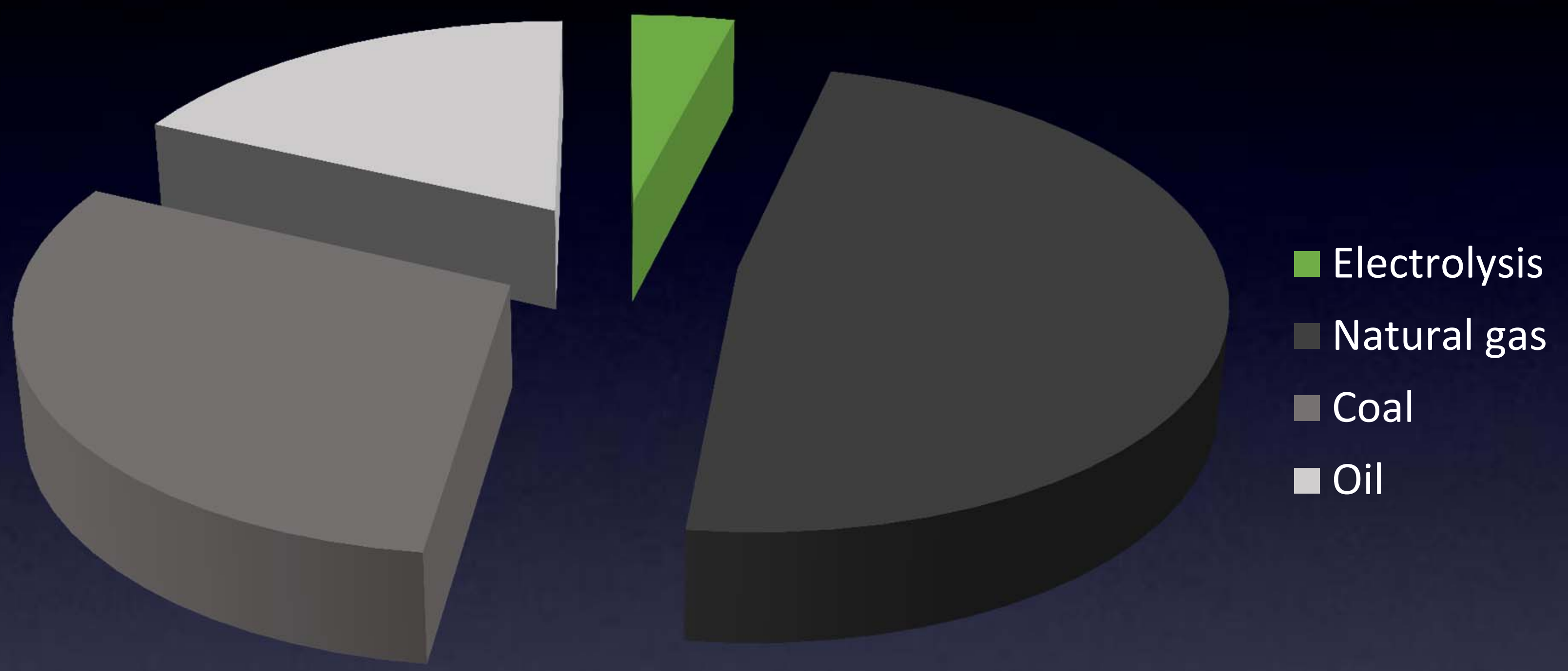
Hydrogen production strategy

Sustainable hydrogen production



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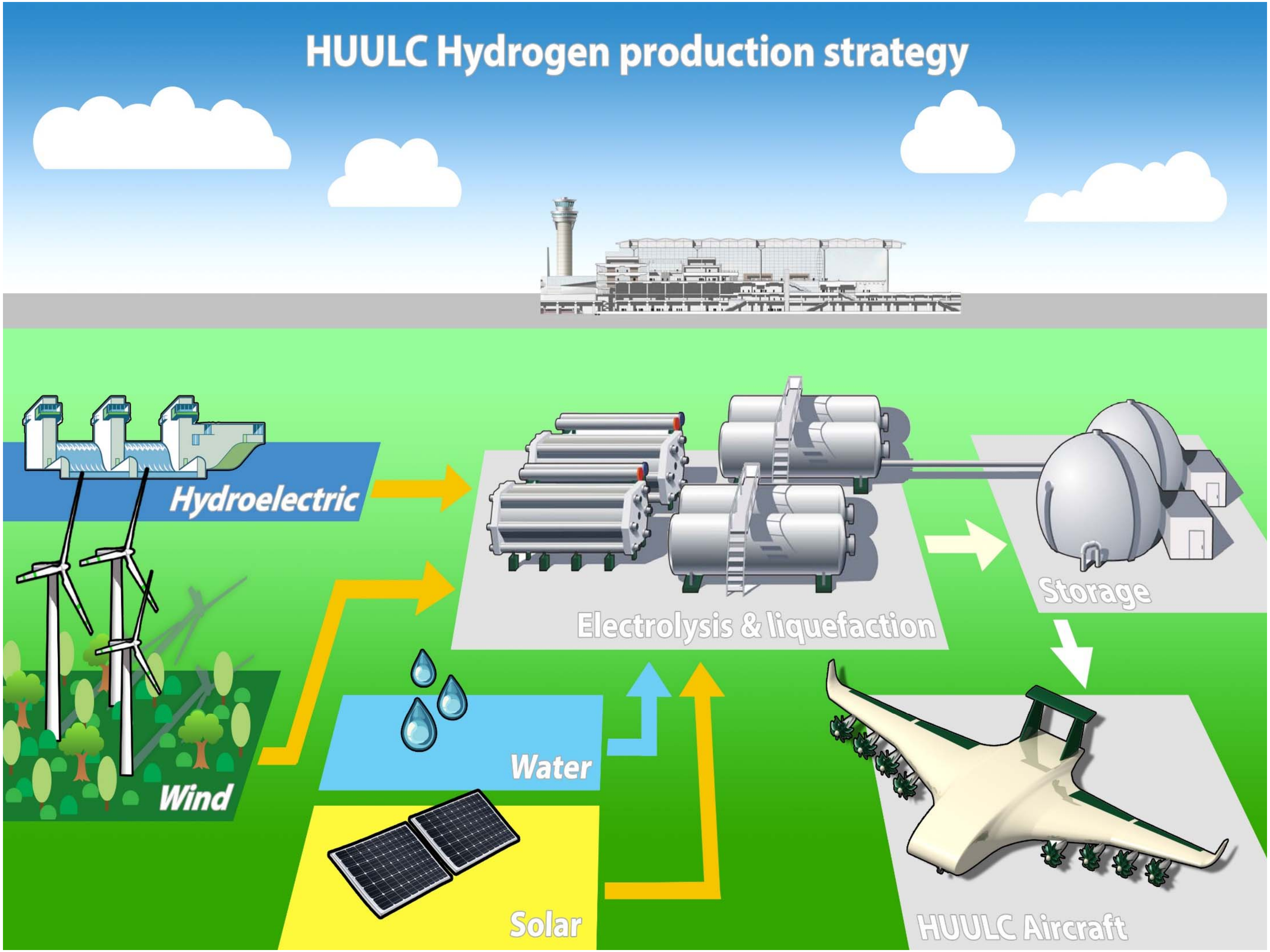
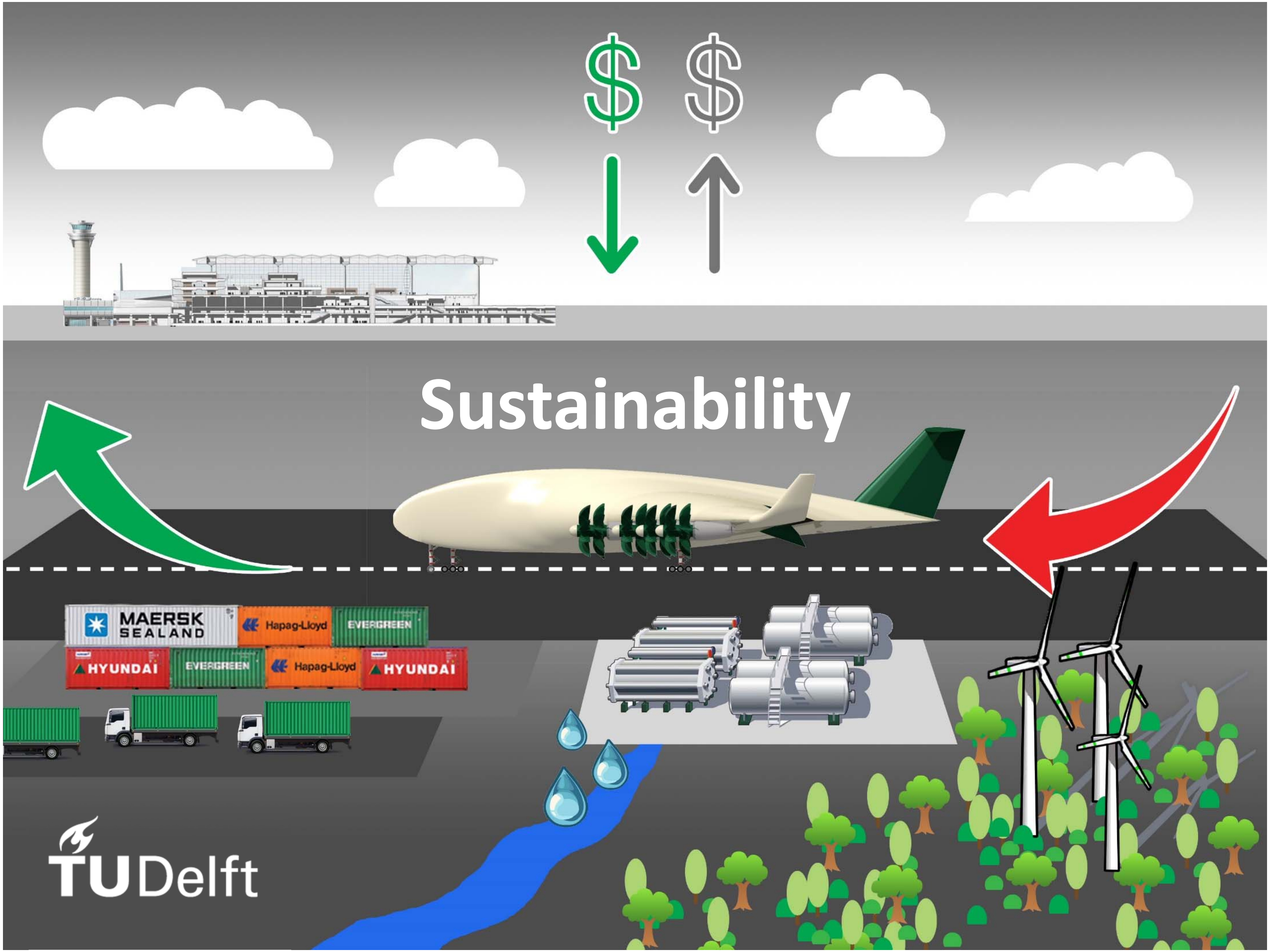

HUULC Hydrogen production strategy
Hydroelectric
Wind
Water
Solar
Electrolysis & liquefaction
Storage
HUULC Aircraft


Sustainability
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NO_x emissions

- Hydrogen
- Premixing
- Lowered cruise altitude

European Commission

Reduction of NOx emissions of 90% by 2050

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CO_2 emissions

	Gigatonnes of CO_2
HUULC fleet (Hydrogen)	0
KUULC fleet (Kerosene)	7.64
Entire EU (2013)	3.74

European Commission

Reduction of CO2 emissions of 75% by 2050

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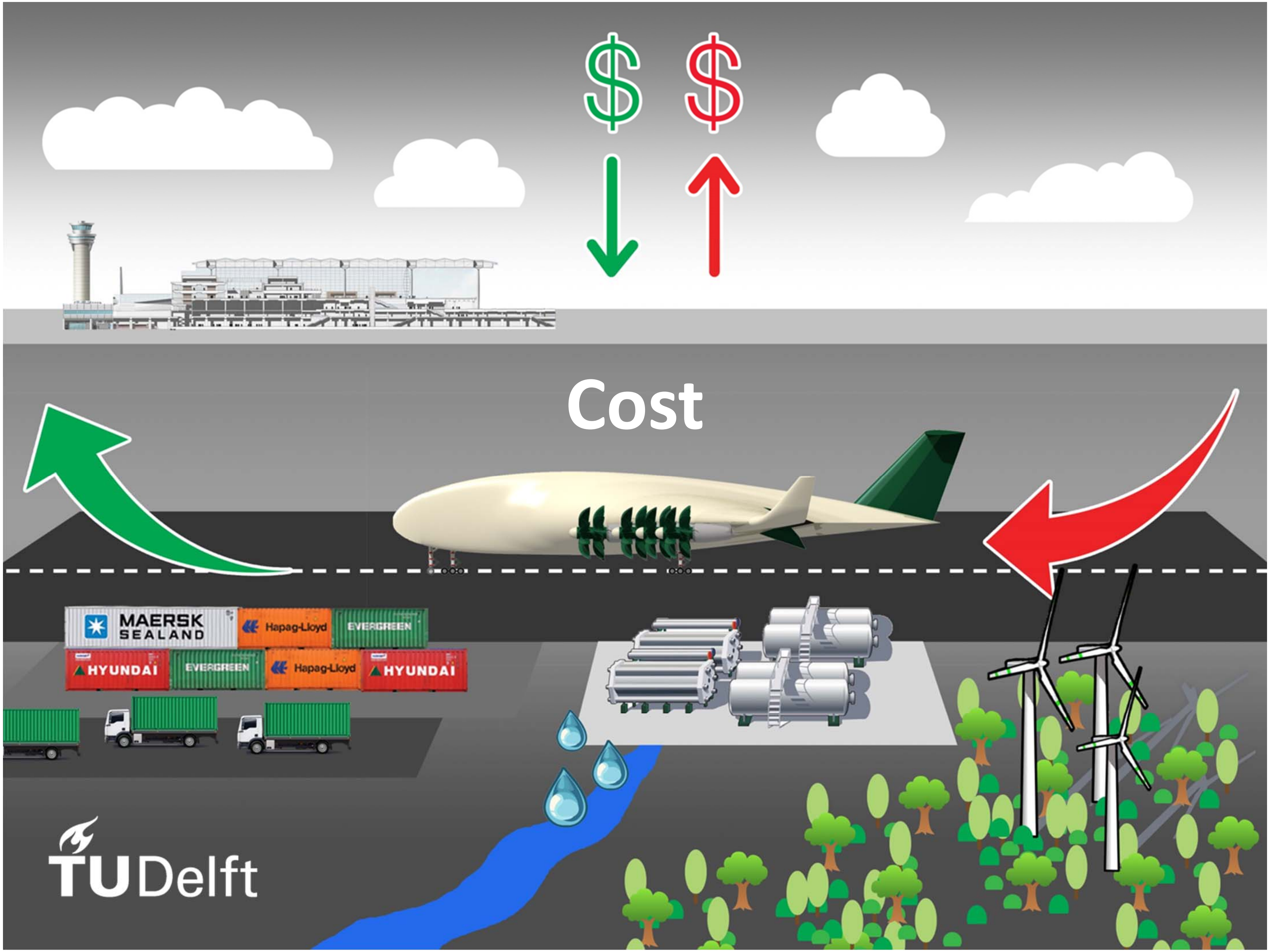
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Cost
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Revenue generated

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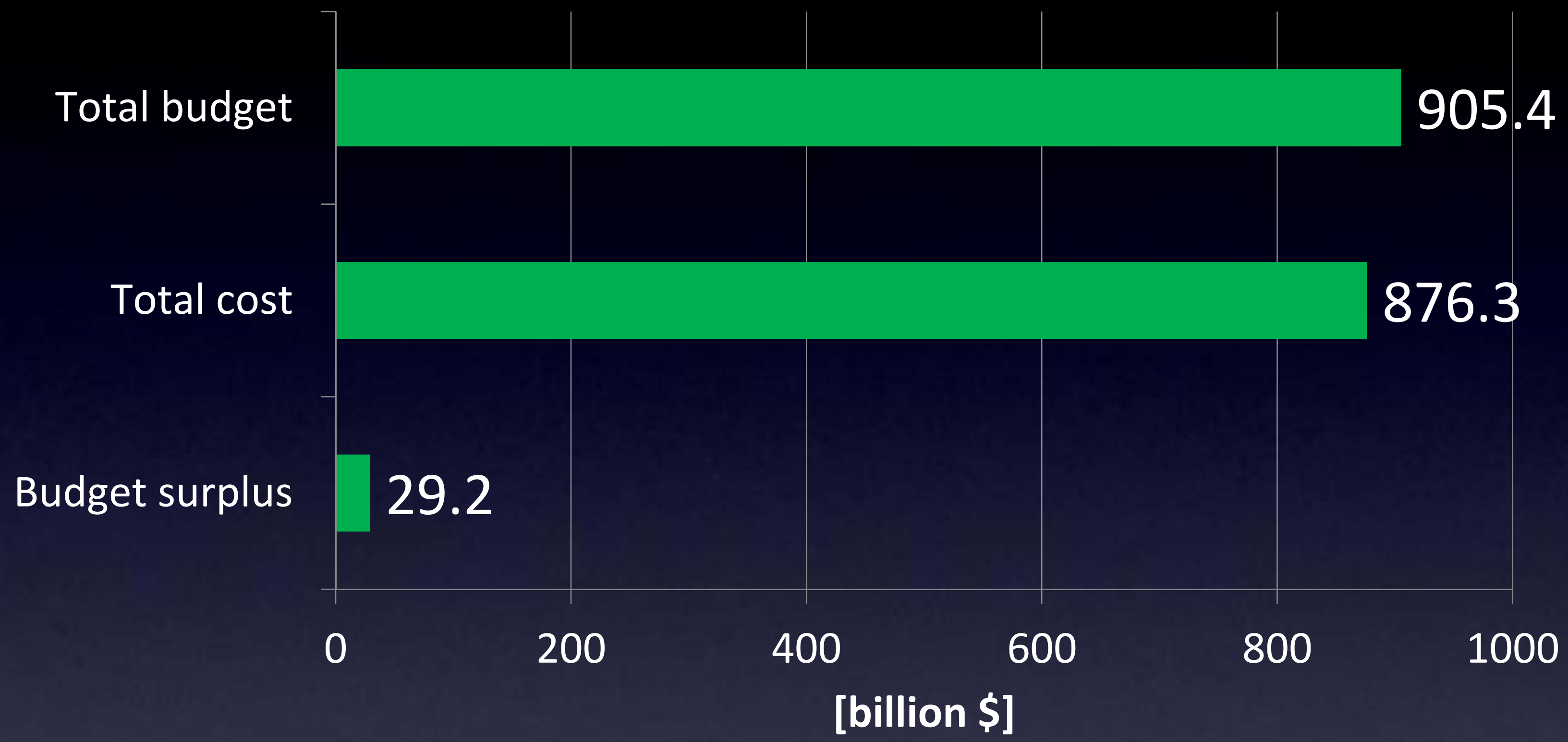
Cost analysis – Overview



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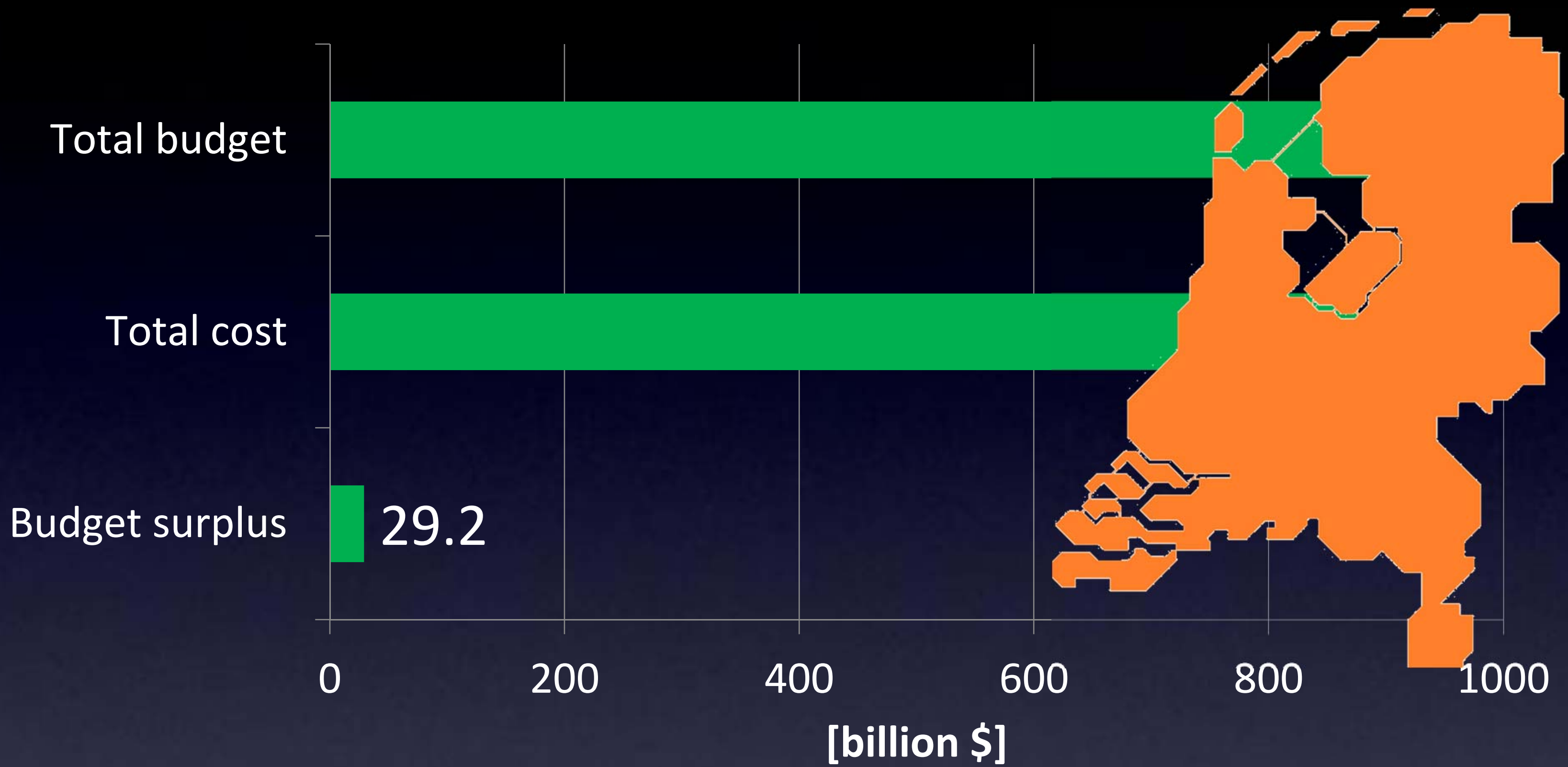
Cost analysis – Overview



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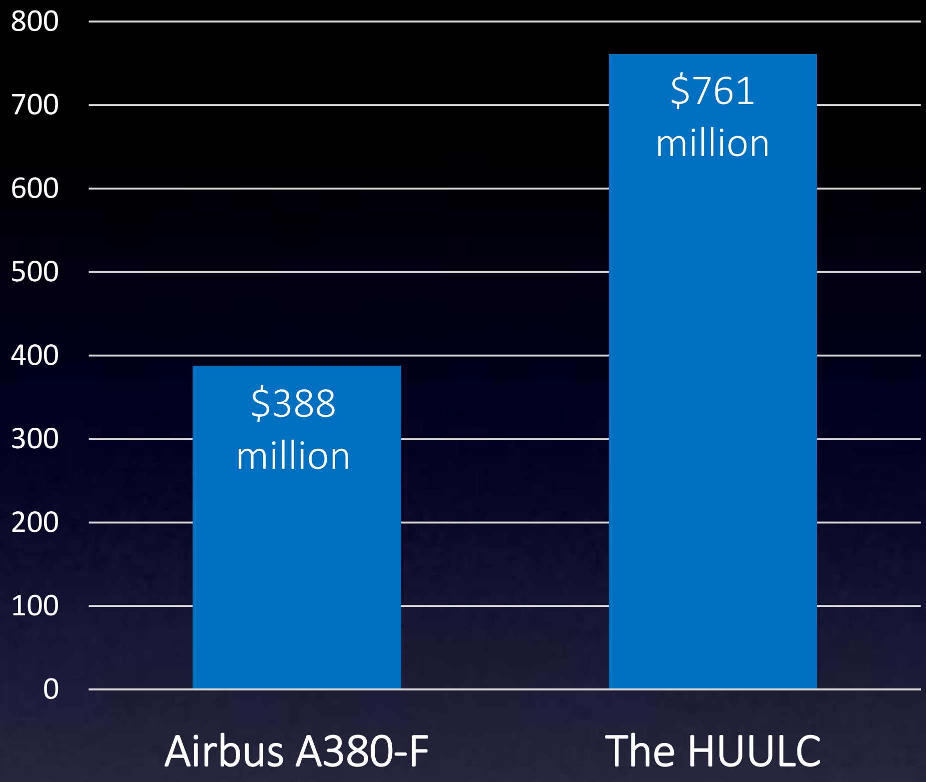
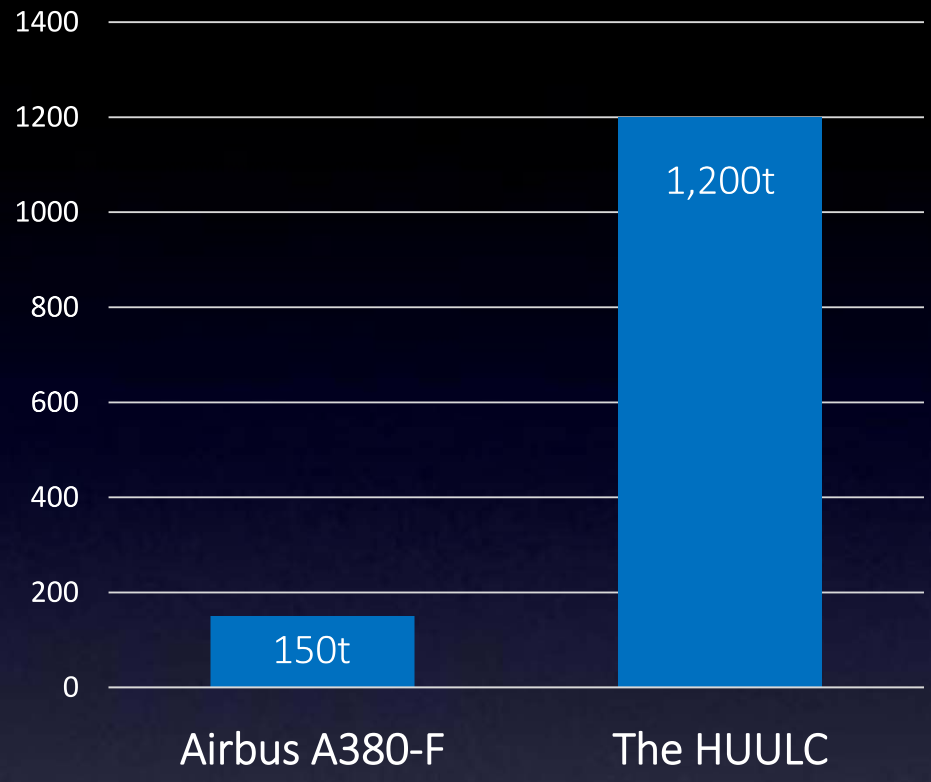
Cost analysis – Price vs payload



2x the price



8x the payload

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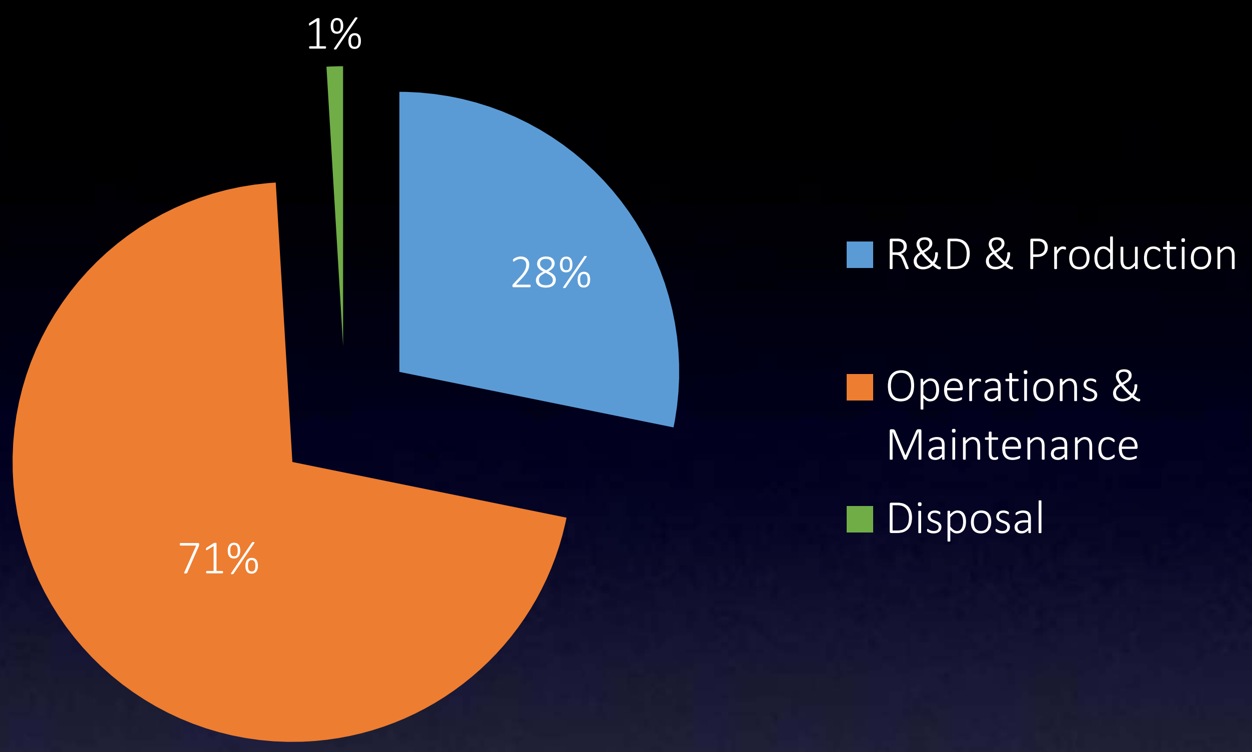
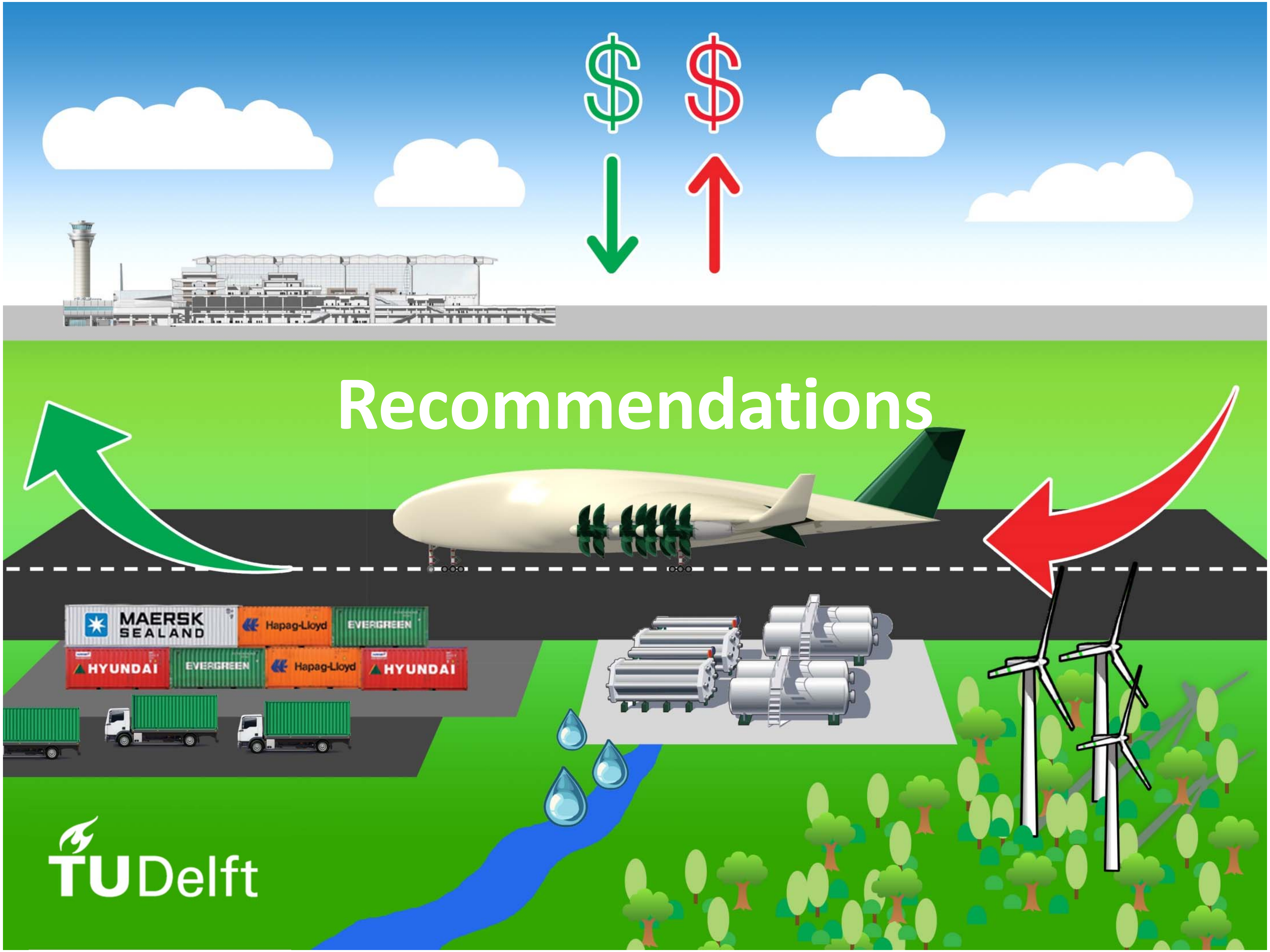
Cost analysis – Breakdown

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Network

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Airport design – Emergency procedures

Alternative airports

Alternative airport	Runway length	Airport distance	Parking spaces
Luxemburg Findel Airport	4000 m	250 km	Few
Schiphol Airport	3800 m	125 km	Few
Berlin Schonefeld Airport	4000 m	670 km	Many

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Thank you.

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