VWS MPP SYSTEMS

The power of teamwork

MPPE: Macro Porous Polymer Extraction System

VWS OIL & GAS

VEOLIA WATER
Solutions & Technologies

Contents presentation

Why MPPE for FLNG?

MPP SYSTEMS

MPPE

AKZO NOBEL

VEOLIA WATER

Solutions & Technologies

Akzo Nobel MPP Systems

VWS MPP Systems

MPP SYSTEMS®

→

MPP SYSTEMS

History of Veolia Environnement

- 1853
  Founding of Compagnie Générale des Eaux (CGE)
- 1875
  Founding of Compagnie Générale Française de Tramways
- 1985
  Forerunners of multiservice contracts
- 1998
  CGE becomes Vivendi
- 1999
  Vivendi Environnement created
- 2005
  A new single name, Veolia

Four businesses

serving the environment

VEOLIA ENVIRONNEMENT

29,6 milliards d'euros de chiffre d'affaires
Plus de 331 000 collaborateurs dans 77 pays

Water	The global benchmark for water services **€12.6 billion**
Waste management	The global benchmark for waste management and resource recovery **€9.7 billion**
Energy services	The global benchmark for energy optimization **€7.3 billion**
Transport	The global benchmark for sustainable mobility **€8 billion** (perimeter Veolia Transdev)

VWS industrial activities

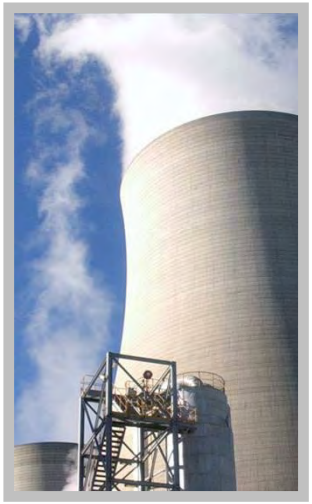
- **Added value** for our customer through our unique knowledge, technologies and services
- **Provide sustainable solutions** from standard equipment to turnkey installation in order to **minimize customers' environmental footprint**
- **Worldwide competences** and experience on many capabilities
- **Market segments**
  - →Automotive
  - →Biofuels
  - →Chemicals
  - →Exploration & production
  - →Food & Beverage
  - →Hydrocarbon processing
  - →Oil & Gas (Upstream & Downstream)
  - →Pharmaceuticals
  - →Primary metals
  - →Power
  - →Pulp & Paper

Formosa Heavy Industry **(Philippines)**

Chevron San Ardo **(United States)**

Capabilities

- → Process Water
- → Produced Water
- → Wastewater
- → Sludge & biosolids
- → Air & Gas
- → Control & Instrumentation
- → Services



Turbomach **(Spain)**

VWS municipal activities

- Ability to **carry out large projects** from proposal to completion
- International network of local BU with **long term partnership**
- **Quick reactivity** and **close working relationship** combined with a **large technologies portfolio** allowing us to work with:
  - →Major cities
  - →Coastal & Tourist area
  - →Rural municipalities

Capabilities

- →Drinking Water
- →Wastewater
- →Sludge & biosolids
- →Air & Gas
- →Control & Instrumentation
- →Services

Qingdao Maidao **(China)** Calgary **(Canada)**

Burj Khalifa lake – Dubai **(UAE)**

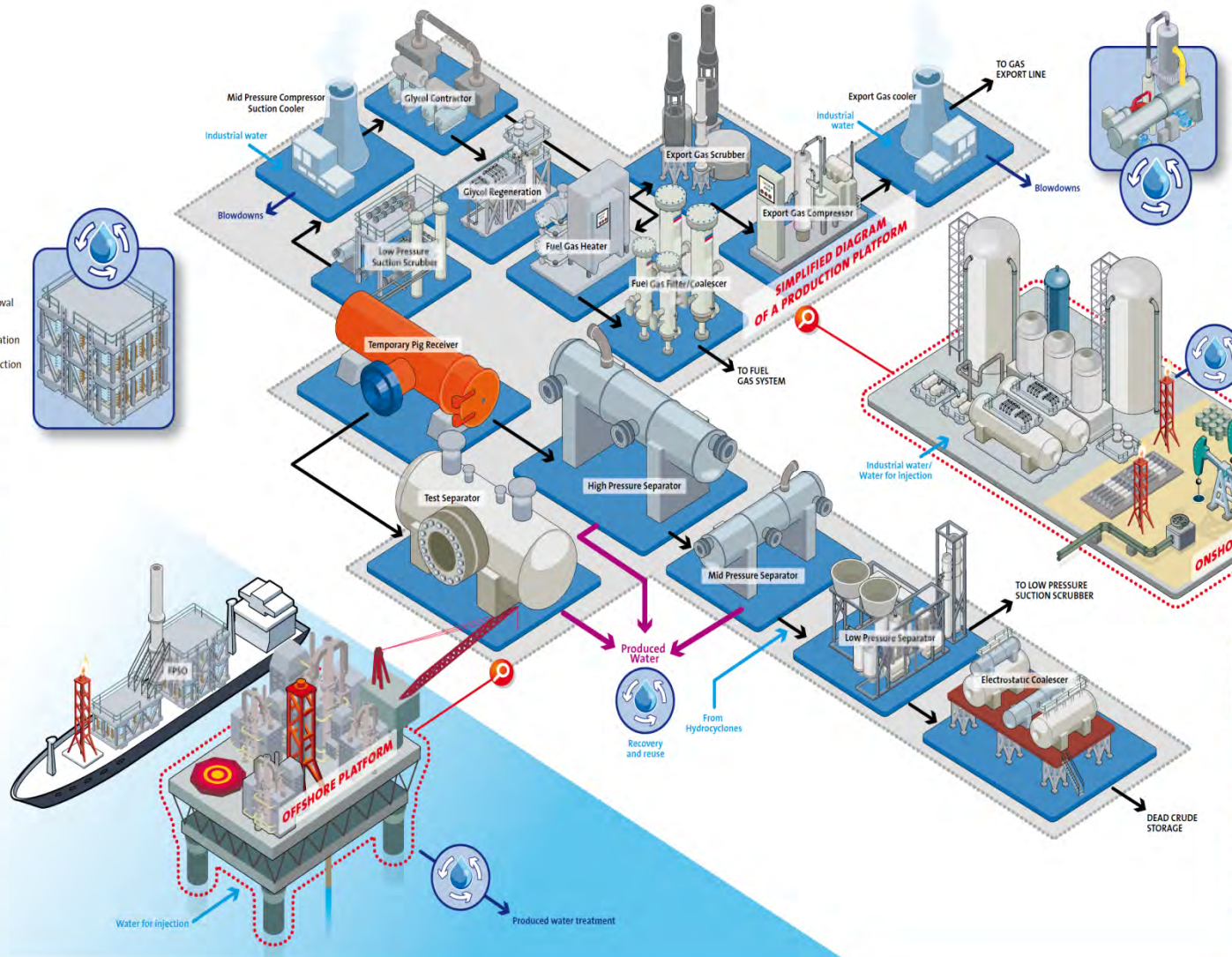
Lucien Grand **(France)**

MPP SYSTEMS

Creating Water Solutions for the UPSTREAM OIL & GAS Industry

VWS OIL & GAS

Integrated approach ensuring quality, safety, reliability



OFFSHORE PRODUCED WATER TREATMENT

› Environmental Compliance
› Reinjection
› Oils, TSS, BTEX, hydrocarbons removal

- Hydrocyclones
- Coarse, media and membrane filtration
- Degassing vessels
- MPPE: Macro Porous Polymer Extraction
- Membrane systems
- Compact flotation units

INJECTION WATER

› Robust and reliable systems
› TSS, Oxygen, TDS removal
› Sulfate Removal

- Coarse filtration
- Pre-treatment systems (membrane and traditional media)
- Membranes
- Nanofiltration (sulfate removal)
- Seawater reverse osmosis (washwater and service water)
- Deaeration packages (vacuum and gas strip)
- Water treatment chemicals

ONSHORE PRODUCED WATER TREATMENT & RECOVERY

› Environmental Compliance
› Alternative resource
› Oils, TSS, BTEX, hydrocarbons removal
› Boron removal
› SAGD process
› Reuse for irrigation, aquifer recharge

- Hydrocyclones
- Plate separators
- Power Clean systems™ Nutshell filter
- Induced gas flotation (IGF) Autoflot™
- MPPE: Macro Porous Polymer Extraction
- Multiflo™ clarification & softening
- Warm lime softening
- OPUS™ technology
- Membranes
- MBBR
- Evaporation and crystallization

A FULL RANGE OF SERVICES

› Maximize productivity and benefits
› Improve performance
› Ensure continuous and secured operations

- **After sales** services (spare parts, consumables...)
- Service deionization
- Water Treatment Chemicals: **HYDREX™**
- Technical maintenance
- Audits & diagnosis
- Control & monitoring
- Operational support 24/7
- Complete **water cycle management and operation**

Training • Package & turnkey plants • Water cycle analysis • Pre-qualification process
Pilot plants • Testing • Commissioning • Technologies integration • Refurbishment & upgrade • Process • Audits
Definition of water needs • Preliminary studies • Engineering • Start-up • Construction • Supervision • Standard equipment & modular solutions • Maintenance

VEOLIA WATER
Solutions & Technologies

Creating Water Solutions for the DOWNSTREAM OIL & GAS Industry

VWS OIL & GAS

Innovative combinations of technologies and services for fully integrated projects

SEAWATER DESALINATION

Thermal desalination:
- Multi-Stage Flash (MSF)
- Multi-Effect Distillation (MED)

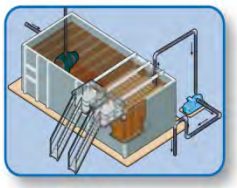
Membranes:
- Pretreatment
- Sea Water Reverse Osmosis (SWRO)

Hybrid combinations:
- RO / Thermal
- Hybrid MED

PROCESS AND DEMIN WATER PRODUCTION
› Safe and high-quality water
› Continuous supply for continuous operation
› Water and energy consumption optimization

UTILITY FEED WATER
› High-volume supply
› Sanitary safety
› High-purified water

- ACTIFLO™ / MULTIFLO™ clarification
- Multimedia filtration
- Activated Carbon
- Softening
- Ion-Exchange demineralization and polishing
- Membranes: UF, MF, NF, Reverse Osmosis



EFFLUENT TREATMENT
› HSE & environmental compliance
› Waste streams segregation for optimal treatment
› Oil / Water separation
› Hydrocarbons and other pollutants removal: PAH, BTEX, aliphatics...
› Health safety
› Energy optimization
› Clean production

RUN-OFF WATER TREATMENT
› Oil removal
› Regulation compliance
› Alternative resource

Pre-treatment:
- Clarification: ACTIFLO™ / MULTIFLO™
- Multimedia Filtration: Sand, activated carbon...

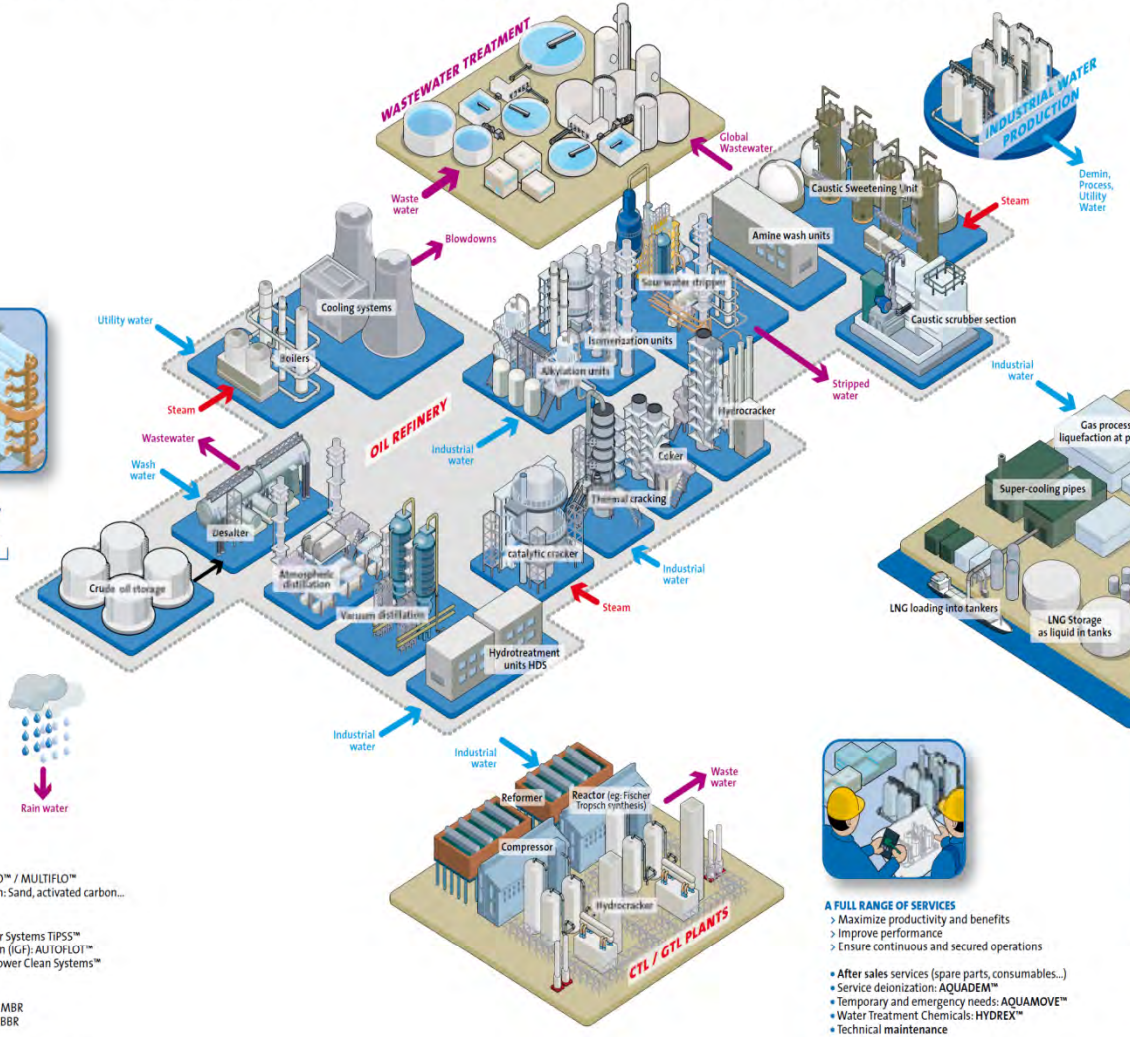
Oil / water separation:
- API separators
- Tilted Plate Separator Systems TiPSS™
- Induced Gas Flotation (IGF): AUTOFLOT™
- Nutshell filtration: Power Clean Systems™

Biological treatment:
- Activated sludge
- BIOSEP™ / NEOSEP™ MBR
- ANOXKALDNESS™ MBBR

Specific applications:
- Macro Porous Polymer Extraction process: MPPE for PAH, BTEX, free oils removal

Polishing: ACTIFLO™

Membranes: UF, Reverse Osmosis



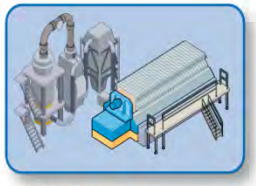
WATER RECYCLING & REUSE
- Tertiary clarification
- Multimedia filtration
- ʒFM™ high performance filtration
- Membranes: Reverse Osmosis

ZERO LIQUID DISCHARGE
› Solutions when no outlet possible
› No cost for effluent disposal
› Produce high-quality distillate for recycling

- Reverse Osmosis (brine concentration)
- Evaporators (falling-, rising-film, MVR...) and Crystallizer

A FULL RANGE OF SERVICES
› Maximize productivity and benefits
› Improve performance
› Ensure continuous and secured operations

- **After sales** services (spare parts, consumables...)
- Service deionization: **AQUADEM™**
- Temporary and emergency needs: **AQUAMOVE™**
- Water Treatment Chemicals: **HYDREX™**
- Technical **maintenance**
- Audits & diagnosis
- Control & monitoring
- Operational support 24/7
- Financing package: **ALL-IN-PACK™**
- Complete **water cycle management** & outsourcing



SLUDGE & BY-PRODUCTS
› Residuals management
› Energy recovery
› Product recovery (oils, solid phase...)

- Triphasic centrifugation
- **BIOTHERM™** anaerobic digestion (Biogas recovery)
- Drying: **INOS™**
- **PYROFLUID™** fluidized bed incineration

Training • Package & turnkey plants • Support & services
Water cycle analysis • Pre-qualification process • Pilot plants • Refurbishment & upgrade
Testing • Commissioning • Process audits • Technologies integration • Maintenance
Definition of water needs • Preliminary studies • Engineering • Start-up • Construction supervision • Standard equipment & modular solutions

VEOLIA WATER
Solutions & Technologies

Contents presentation

MPP SYSTEMS

MPPE

Removal of Dissolved and Dispersed Hydrocarbons

from

Offshore Produced Water,

Wastewater,

Process water,

Groundwater,

with Macro Porous Polymer Extraction (MPPE)

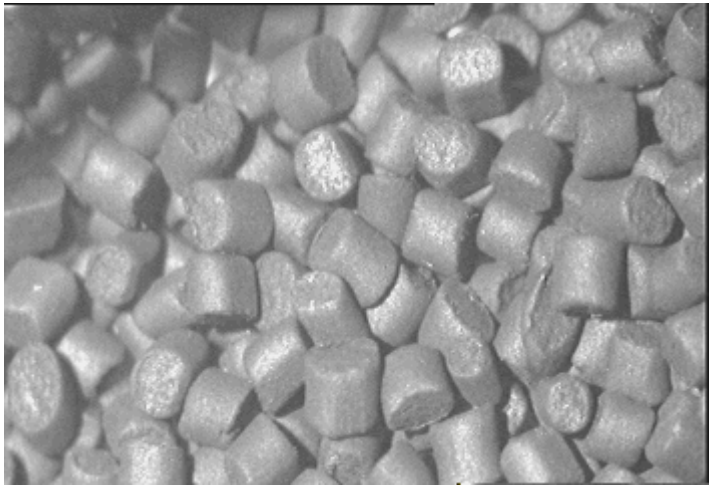
by

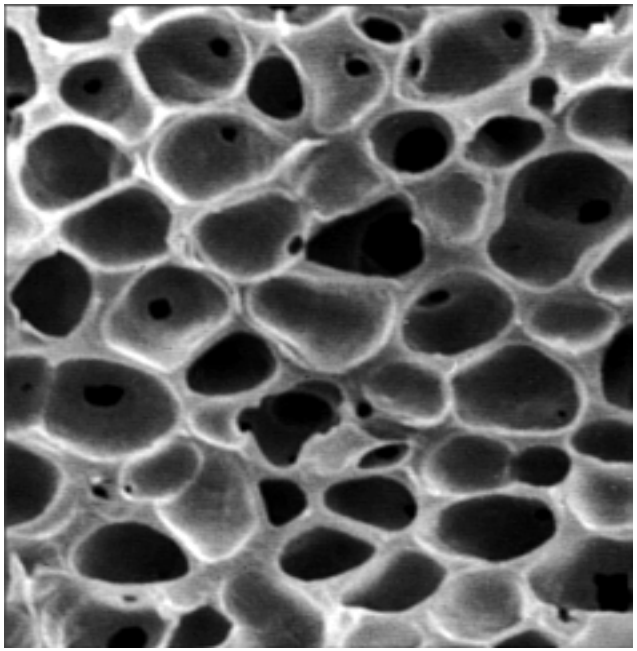
VWS MPP Systems B.V.
www.vwsmppsystems.com

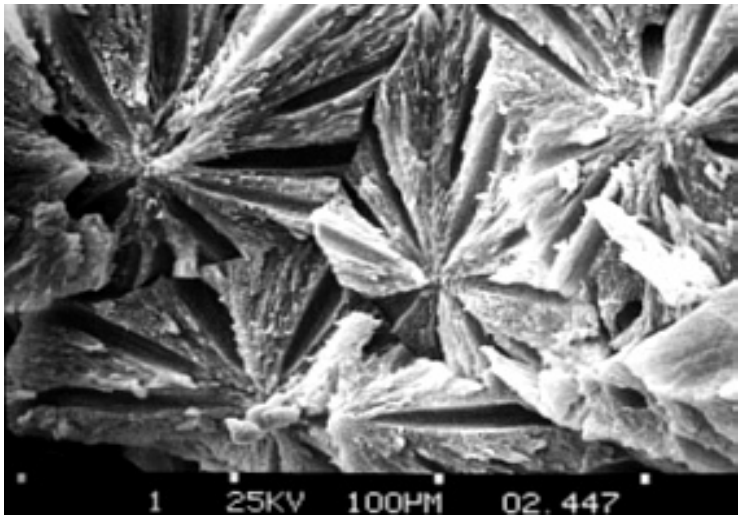
MPP SYSTEMS

MPPE

MPP Structure

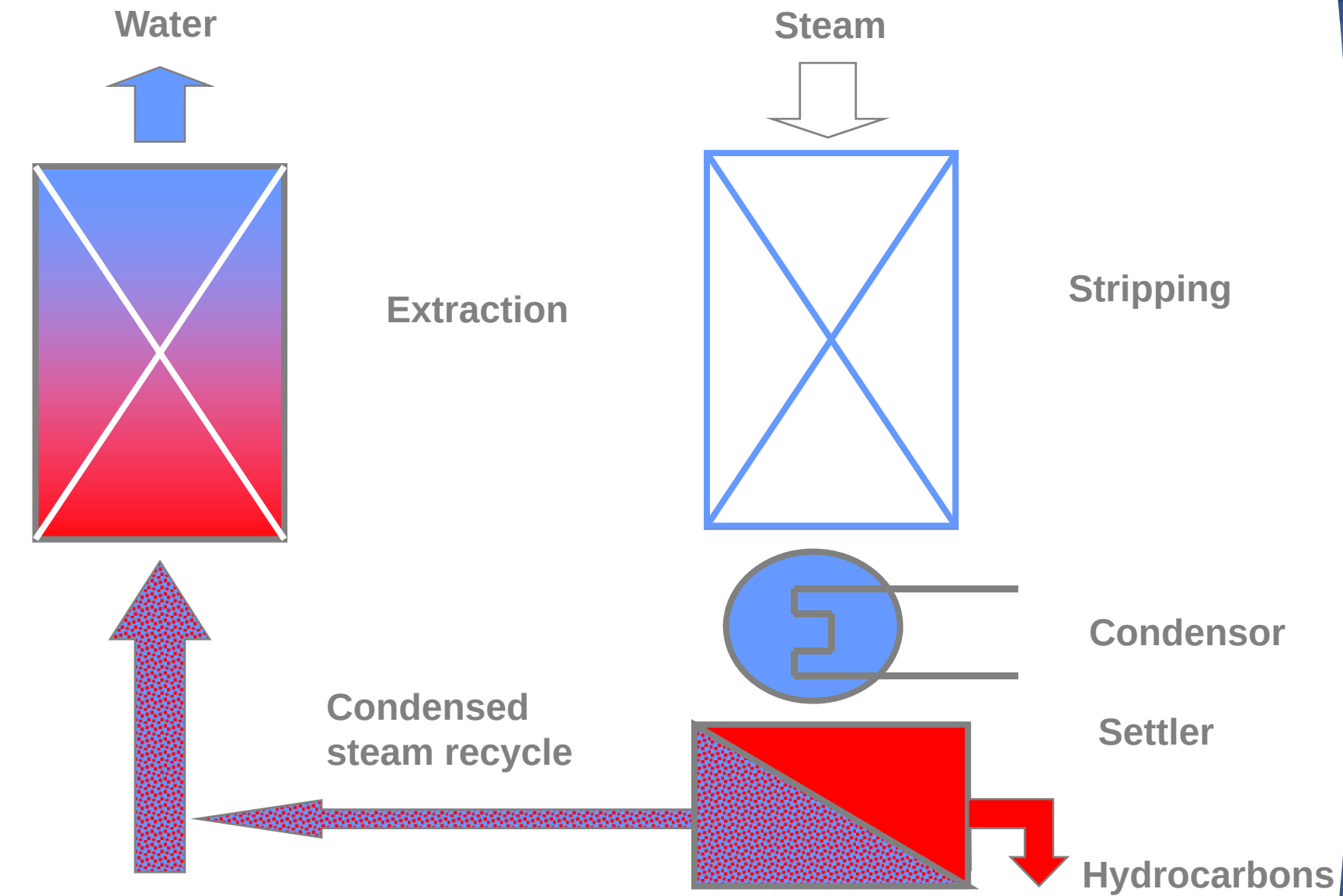






MPP SYSTEMS

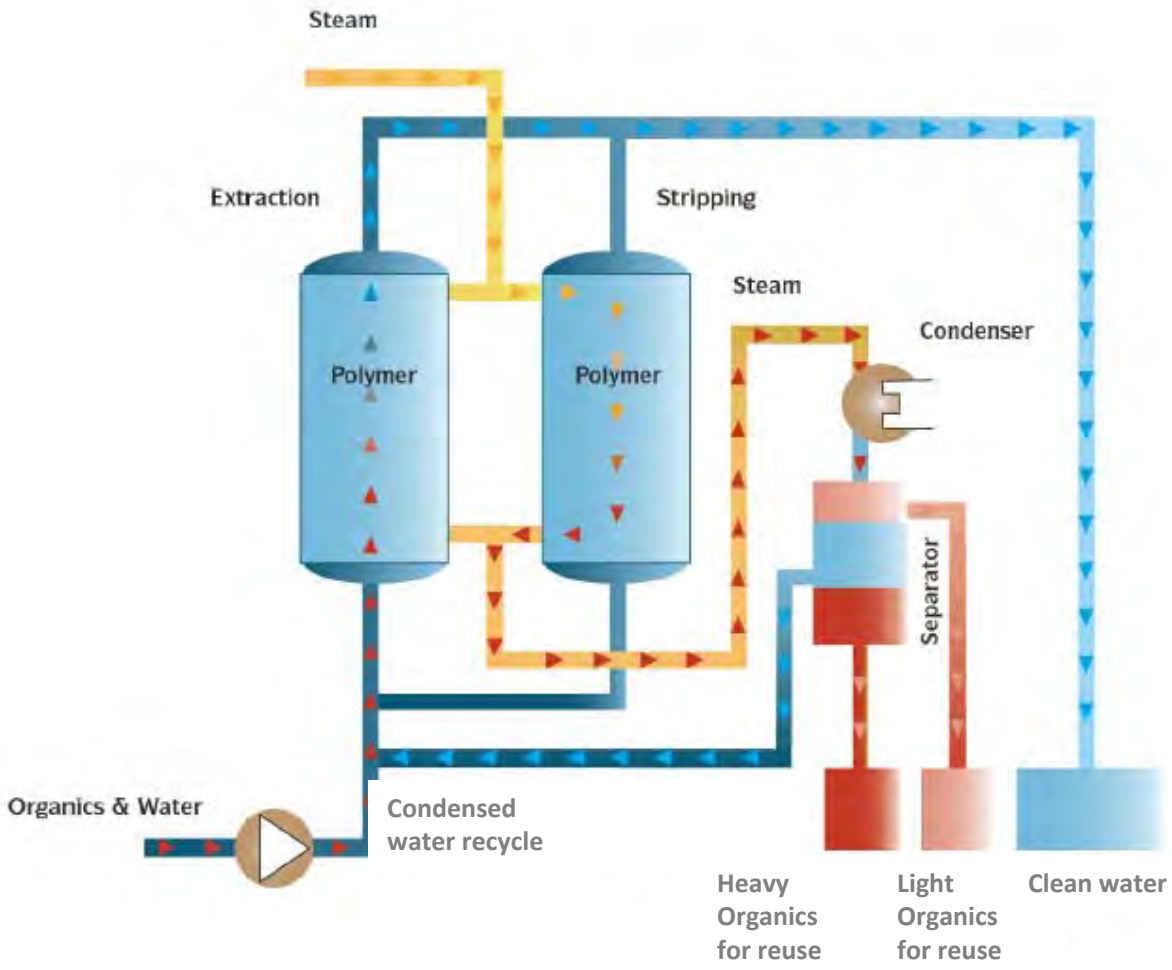
MPPE process (1)



MPP SYSTEMS

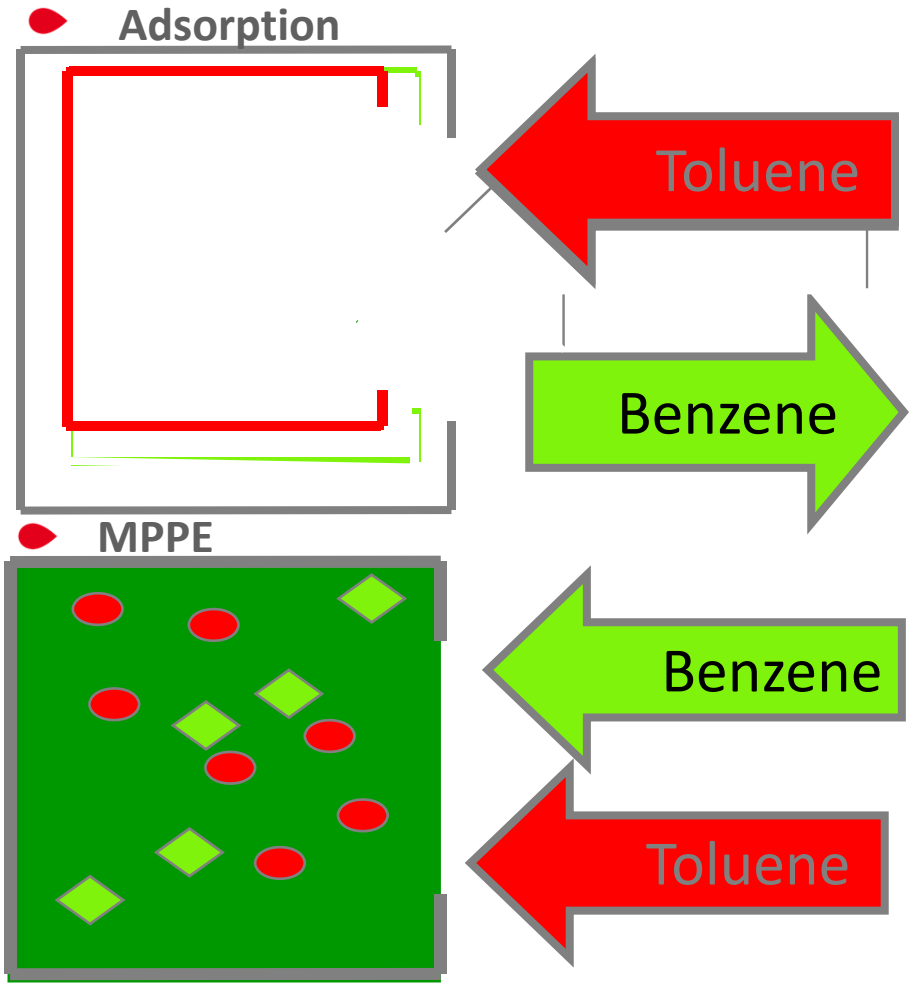
MPPE

MPPE process (2)



MPP SYSTEMS

MPPE Extraction versus AC-adsorption



- Toluene supersedes Benzene
- More “other” molecules requires more Activated Carbon
- Sensitive for fouling

- Molecules do not “see” each other
- More “other” molecules require not more MPPE
- Not sensitive for fouling

MPP SYSTEMS

Components removable with MPPE

MPPE

Aromatic and Aliphatic Compounds

Benzene
Toluene
Ethyl Benzene
Xylene(s)
Cumene
Limonene
Nitrobenzene
Higheralkylated phenols
Octanol
Nonanol
Decanol
Hexane
Heptane
MIBK
TetraHydroTiophene
CS_2
Tetramethyltetrahydrofuran
MTBE
Etc.

Halogenated/ Chlorinated Compounds

Monochloromethane
Dichoromethane
Trichloromethane
Tetrachloromethane
Dichloroethane (1,1 & 1,2)
Trichloroethane
Tetrachloroethane
Chloroethylene
Dichloroethylene
Trichloroethylene
Tetrachloroethylene
Trichloropropane
Chlorobutadiene
Hexachlorobutadiene
Monochlorobenzene
Dichlorobenzene
Chlorobenzenes
Chloroaphtalene
Hexachlorocyclohexane
Monochlorophenol
Dichlorophenol
Trichlorophenol
Dichloro-di-isopropylether
Dioxins
Etc.

Polyaromatic Hydrocarbons

PCBs
Acenaphthylene
Acenaphthene
Fluorene
Anthracene
Fluoranthene
Pyrene
Benz(a) anthracene
Chrysene.
Etc.

NPDs
Naphtalenes
Phenanthrenes
Dibenzothiophenes

MPP SYSTEMS

MPPE Features
Flexibility/ Robustness

- High reduction factor
- Reduction factor independent of inlet concentration
- Robust against water environment (surfactants, salts, pH range 3 - 9 etc.)
- Predictable performance
- Flow/ Inlet concentration flexibility
  - 10% lower flow: 50% higher inlet concentration possible
  - lower inlet concentration: higher flow possible
- Capacity flexibility
  - turn up / down ratio e.g. 0 to 150% of design capacity
- Batch wise operation; Immediate performance at start up
- Separated hydrocarbons (~ 100% pure) for (re)use
- No waste stream, no air emission
- 100% recovery of water and hydrocarbons

MPP SYSTEMS

Markets / Applications

- Industries
  - Offshore
  - Oil & Gas
  - Petrochemical
  - Chemical
  - Pharmaceutical
  - Coatings
  - Electronics
- Government

- Offshore produced water : 25%
- Industrial waste water : 35%
- Groundwater / DNAPL : 40 %

- Customers e.g.
  - TOTAL
  - Gaz de France
  - NAM (Shell/Exxon)
  - Statoil
  - Shell
  - Dupont
  - Degussa
  - Albemarle
  - AkzoNobel
  - Philips
  - Woodside
  - Western Refining
  - Inpex
  - BP

MPPE

Elf Aquitaine / Total / Vermilion Harlingen
gas produced water treatment

Column size (m): d = 0.8, h = 2.0

Dispersed oil and BTEX removal

Since June 1994

- Produced water offshore gas
- Condensed water from MEG unit
- Dissolved / disperse aromatics
  1,500 – 2,500 ppm → < 0.5 ppm
- Dispersed oil (aliphatics)
  160 – 350 ppm → < 0.5 ppm
- Flow 4 m^3/hr

Since June 1997

- Produced water offshore gas
- Condensed water MEG unit
- Rainwater / fun off water
- Groundwater
- 6 m^3/hr

MPP SYSTEMS

AkzoNobel / Organon (Merck SD) groundwater treatment 1994

- Oss (NL)
- Pharmaceutical RM supplier
- 40 m^3/hr
- Aromatics, chlorinated (250 ppm)
- Effluent < 0.5 ppm
- Iron 48 ppm, Ca 65 ppm
- Since December 1995

MPP SYSTEMS

MPPE

MPPE groundwater Lenoir (USA)

MPP SYSTEMS

MPPE

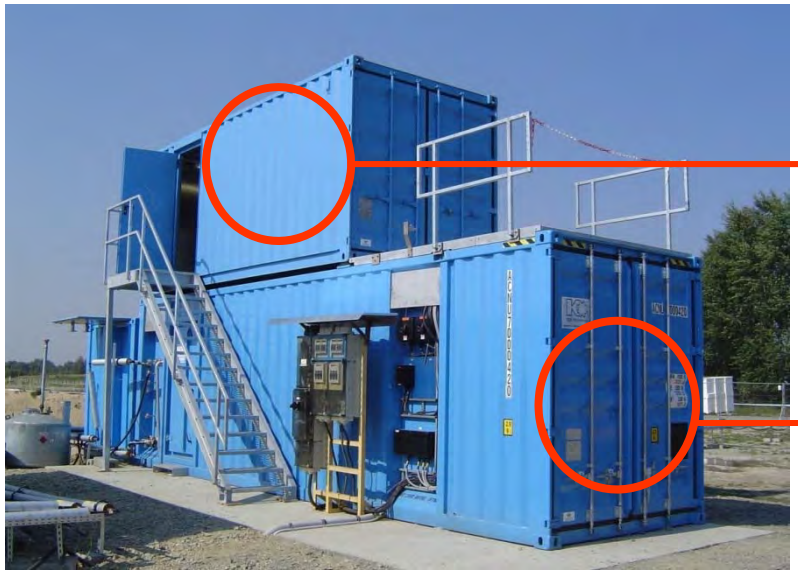
MPPE Schwarze Pumpe
Groundwater 2002

Two years of intensive testing

MPP SYSTEMS

MPPE

Five MPPE units, LMBV, Schwarze Pumpe Germany



- Groundwater since 2004
- 20 m^3/hr
- BTEX 233,000 µg/l (ppb)
- Naphatalene 500 µg/l (ppb)
- PAHs 153 µg/l (ppb)
- > 99% removal
- Performance guaranteed

MPP SYSTEMS

MPPE

Two MPPE units, LMBV, Lauchhammer Germany

- Groundwater Dec. 2010
- 3 m^3/h
- BTEX 30,000 → 150 ppb
- PAK 500 → 15 ppb
- Performance guaranteed

MPP SYSTEMS

MPPE

Germany plant Ruhrgebiet

Groundwater 120 m3/h

MPP SYSTEMS

MPPE

MPPE treatment of Tank Cleaning water with waste / ground / surface water

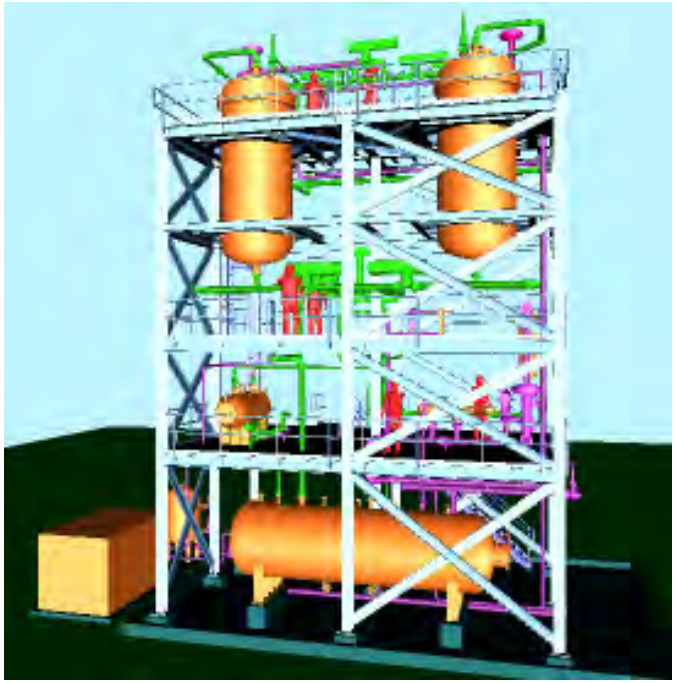
DOW;; LBC Rotterdam

MPP SYSTEMS

MPPE

Western Refining Gallup USA

3 D model Western Refining USA
MPPE unit, built in USA,
start up for April 2012



MPP SYSTEMS

MPPE System Gaz de France (France)

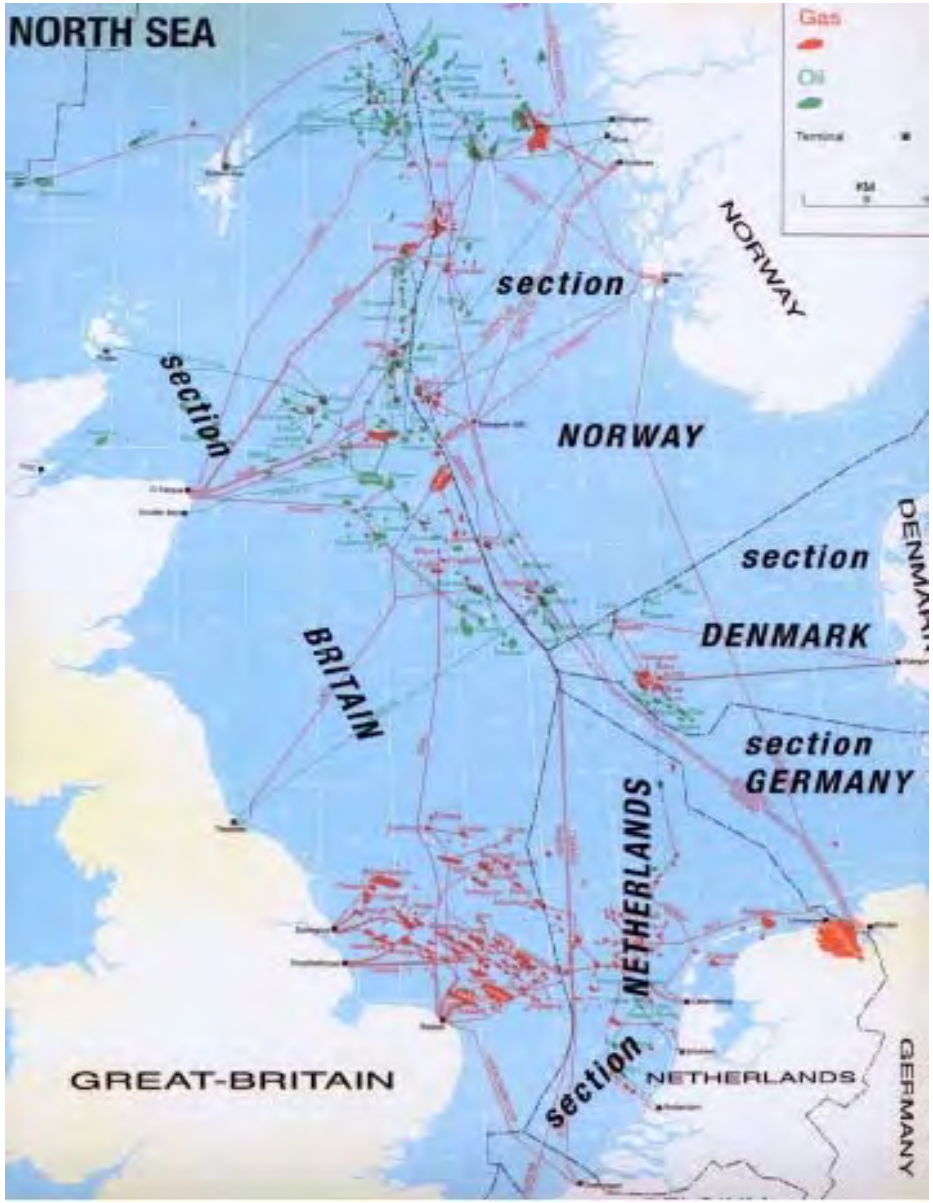
- Underground gas storage
- Processwater
- 3 m^3/hr (13 gpm)
- THT (odour)
- 50 → 0.5 ppm
- ≥ 99% removal
- Since 2001

MPP SYSTEMS

Contents presentation

MPP SYSTEMS

MPPE



MPP SYSTEMS

Survey Emission Regulations 1/3

- North East Atlantic / North Sea
  - 1978: 40 ppm dispersed oil (PARCOM)
  - 2007: 30 ppm dispersed oil (OSPAR)

Individual countries

- The Netherlands: Reduction Benzene / Aromatic discharge
  - 1994: Benzene / Aromatic reduction of 80% in 2000
  - 1998: NOGEPA study 55 technologies (MPPE Number 1)
  - 1999: NAM offshore fieldtest L_2 (OTC paper)
  - 2002 / 2003: First commercial offshore MPPE units TOTAL; NAM

MPPE

NAM (Shell/Exxon) offshore MPPE field test 1999

MPP SYSTEMS

MPPE

NAM (Shell/Exxon) offshore MPPE field test 1999

MPP SYSTEMS

MPPE

MPPE Offshore Demo unit

MPP SYSTEMS

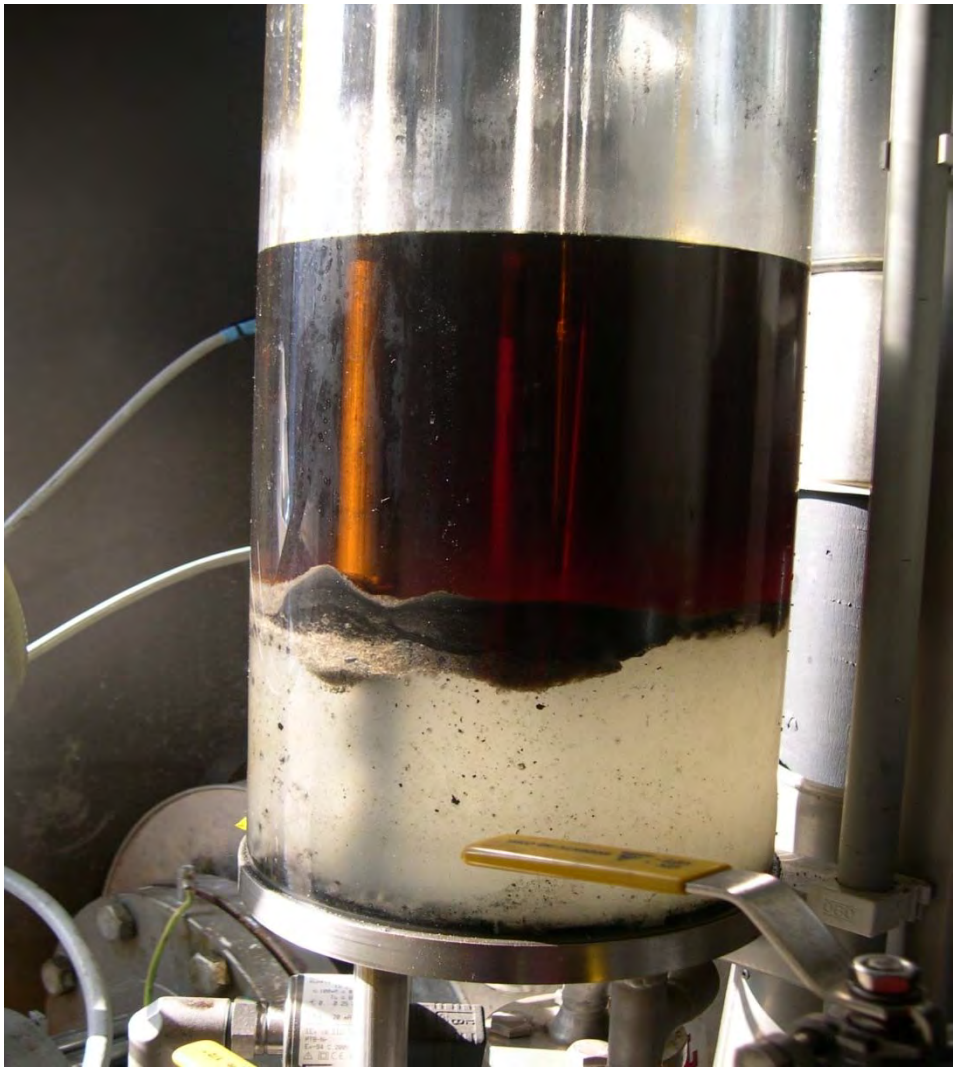
MPPE

MPPE Offshore demo unit

MPP SYSTEMS

MPPE

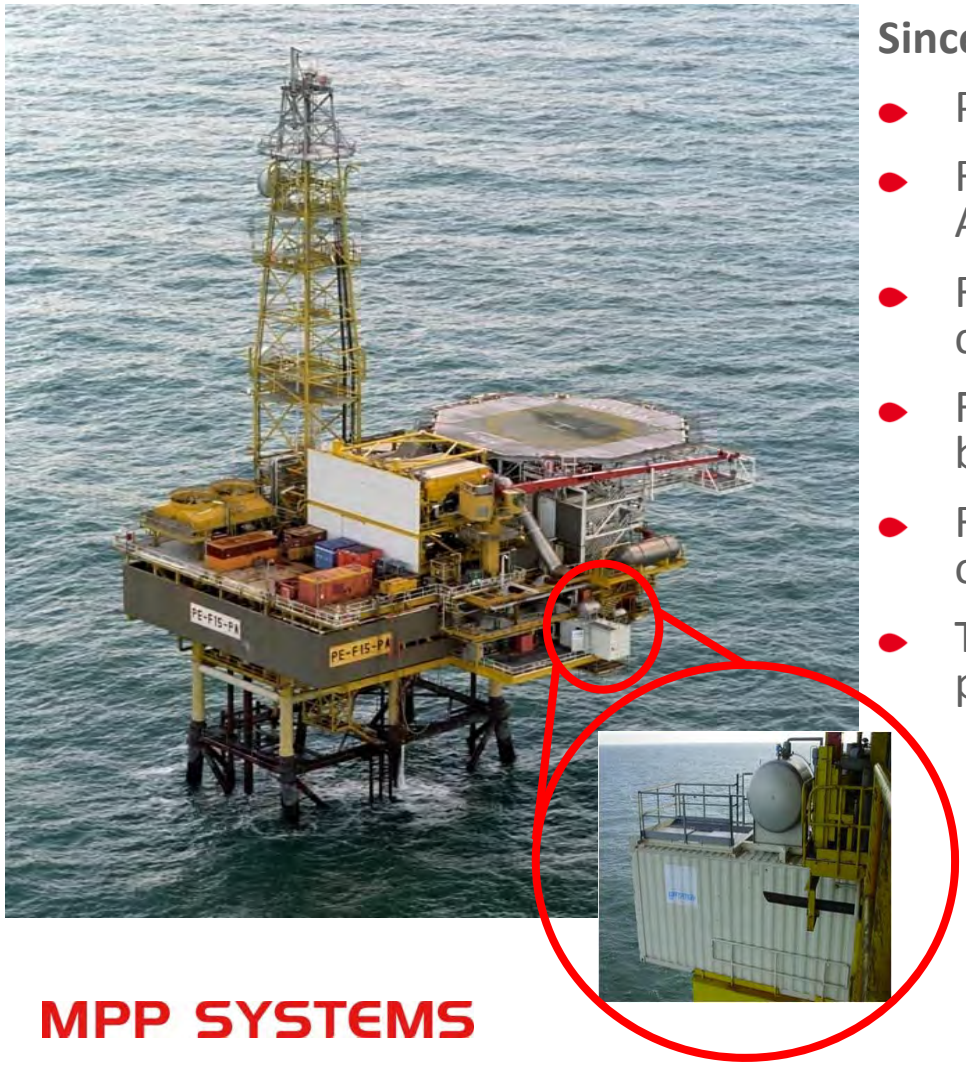
MPPE Separator



MPP SYSTEMS

MPPE

TOTAL offshore F15A (unmanned)



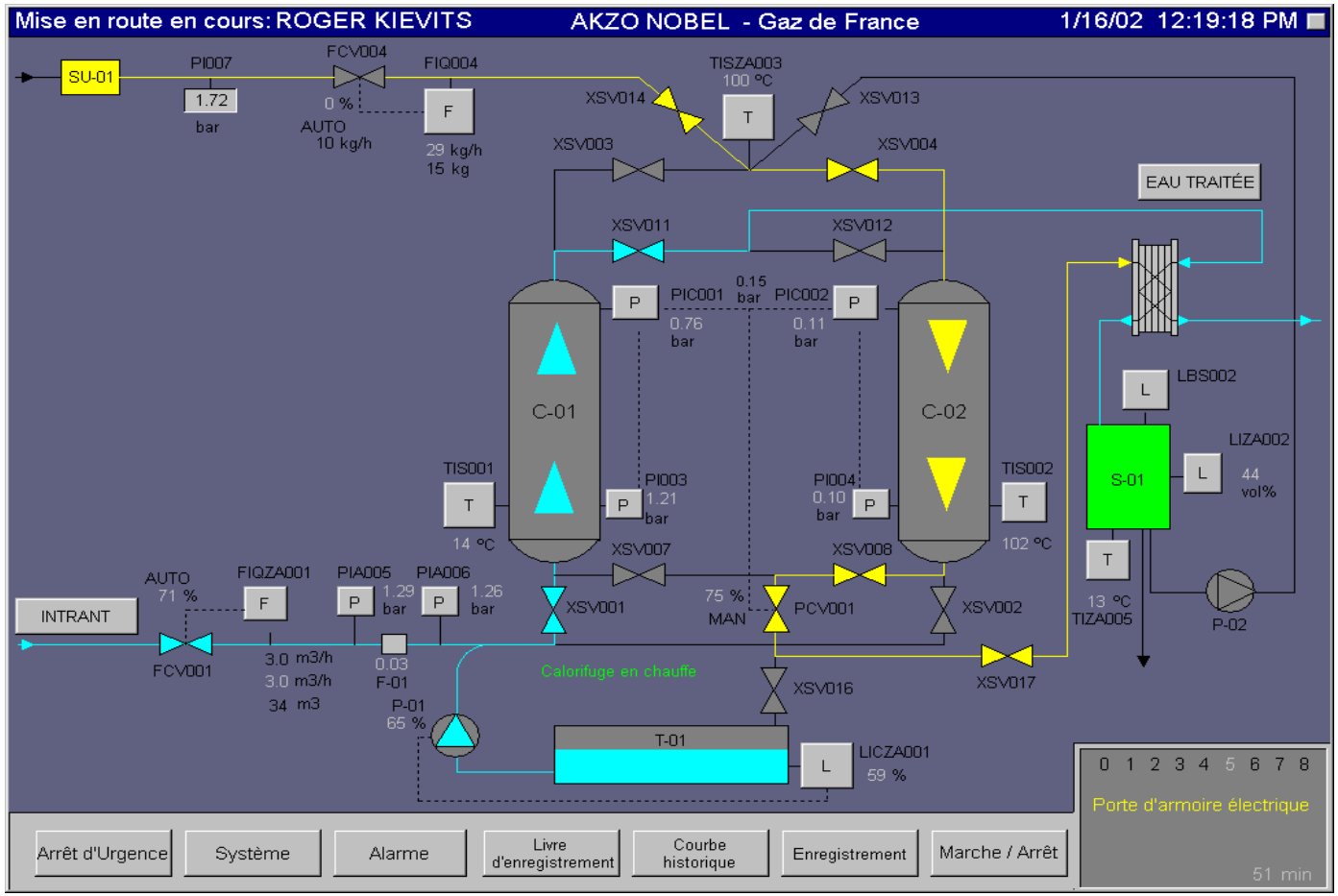
Since January 2002

- Produced water from offshore gas
- Removal of dispersed and dissolved Aliphatics, Aromatics, and PAHs
- Robust against salt, surfactants, corrosion inhibitors
- Fulfilling TOTAL's environmental goal beyond present legal requirements
- Remote controlled to enable unmanned operation
- To save space the MPPE unit is installed partially over the platform edge

MPP SYSTEMS

MPPE

MPPE remote control



MPP SYSTEMS

Survey Emission Regulations 2/3

- North East Atlantic / North Sea (OSPAR)
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  - 1999: NAM offshore fieldtest L_2 (OTC paper)
  - 2002 / 2003: First commercial offshore MPPE units TOTAL; NAM
- Norway
  - 2002: Zero Harmful Discharge in 2007
  - Environmental Impact Factor (EIF)

MPPE

Oil & Gas produced water composition

Hydrocarbons	Non polar	More polar
Dispersed oil Floating (sheen)	Alphatics: 200-1000 ppm Separators / flotation "Standard": 40 ppm "Advanced": 10-30 ppm	Negligible
Dissolved Not floating		
"non toxic"	**Aliphatics**	**Alcohols/Methanol/Glycol Carboxylic acids Hundreds of ppm**
Toxic Carcinogenic Mutagenic	**Aromatics BTEX 200 – 3,000 ppm PAHs 200 – 80,000 ppb**	**Alkyl Phenols Ten – Hundreds ppb**

MPP SYSTEMS

Produced Water composition

Compounds	ppm	Composition
Dispersed oil =	200 - 1,000 (gas)	DA
Dispersed hydrocarbons =		
Dispersed Aliphatics = floating		
Dissolved hydrocarbons		B
Toxic:		
- Benzene	Aromatics 200 – 3,000	T
- Toluene		
- Ethyl benzene		E
- Xylene		X
- PAHs and NPDs	0.2 - 80	PAHs
- Alkyl Phenols	0.1 - 0.2	APh
Dissolved hydrocarbons Readily Biodegradable	hundreds	Polar
Polar:		
- Acids		
- Alcohols (Methanol)		

MPP SYSTEMS

Produced Water composition

Compounds	ppm	Composition	Ospar
Dispersed oil =	200 - 1,000 (gas)	DA	DA
Dispersed hydrocarbons =			
Dispersed Aliphatics = floating			
Dissolved hydrocarbons		B	B
Toxic:			
- Benzene	Aromatics 200 – 3,000	T	T
- Toluene			
- Ethyl benzene		E	E
- Xylene		X	X
- PAHs and NPDs	0.2 - 80	PAHs	PAHs
- Alkyl Phenols	0.1 - 0.2	APh	APh
Dissolved hydrocarbons Readily Biodegradable	hundreds	Polar	Polar
Polar:			
- Acids			
- Alcohols (Methanol)			

MPP SYSTEMS

Environmental Impact Factor

- Investigation Norwegian Offshore Industry (esp. Statoil)
  - Impact of Individual compounds on Environment
- Type of molecules and concentration determine Impact on Environment
- More toxic molecules:
  - Higher multiplication factors to reflect environmental impact
- Environmental Impact Factor:
  specific molecules or groups of molecules are expressed in % of the total 100% Environmental Impact of that particular produced water stream in that particular environment

Produced Water composition

Compounds	ppm	Composition
Dispersed oil =	200 - 1,000 (gas)	DA
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Dissolved hydrocarbons		B
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Polar:		
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- Alcohols (Methanol)		

MPP SYSTEMS

Produced Water composition

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Dissolved hydrocarbons		
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- Xylene		
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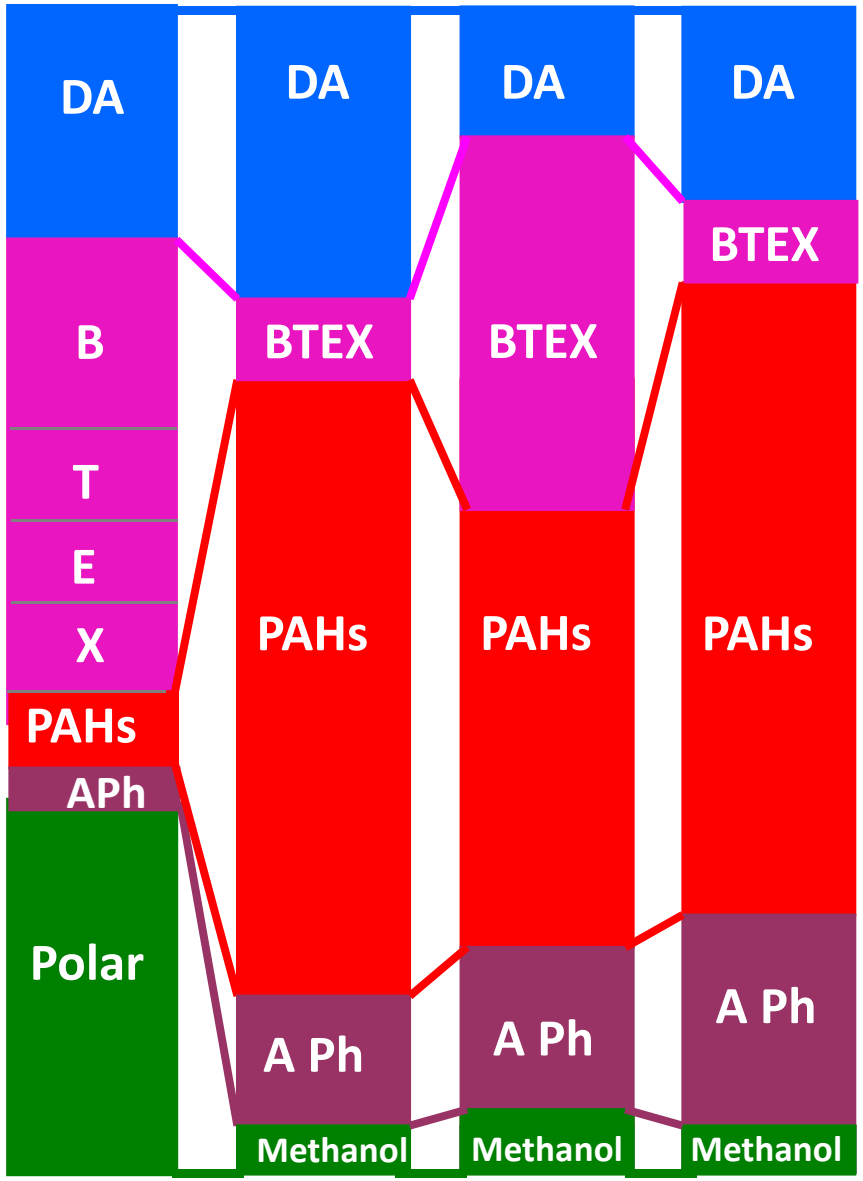
Dissolved hydrocarbons Readily Biodegradable	hundreds	
Polar:		
- Acids		
- Alcohols (Methanol)		



MPP SYSTEMS

* EIF = Environmental Impact Factor

Produced Water composition

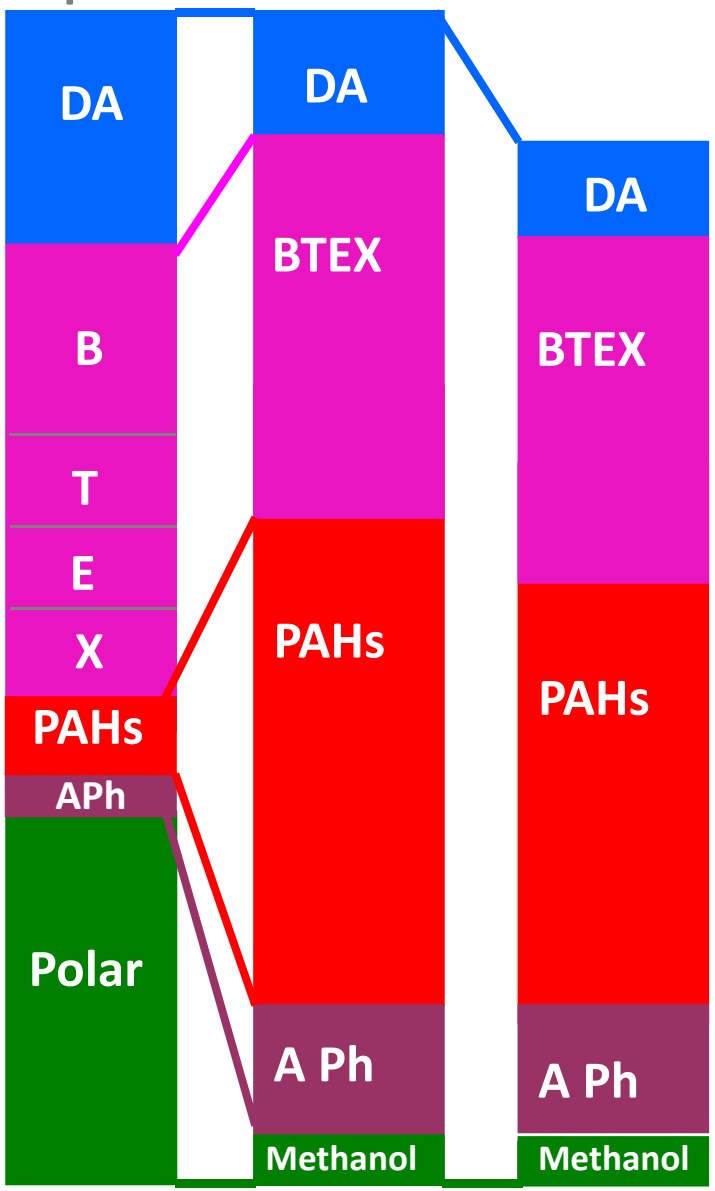
Compounds	ppm	Composition	EIF*
Dispersed oil =	200 - 1,000 (gas)	DA	DA
Dispersed hydrocarbons =			
Dispersed Aliphatics = floating			
Dissolved hydrocarbons Toxic:			
Toxic:		B	BTEX
- Benzene	Aromatics 200 – 3,000	T	
- Toluene		E	
- Ethyl benzene		X	
- Xylene			
- PAHs and NPDs	0.2 - 80	PAHs	PAHs
- Alkyl Phenols	0.1 - 0.2	APh	
Dissolved hydrocarbons Readily Biodegradable	hundreds	Polar	
Polar:			A Ph
- Acids			
- Alcohols (Methanol)			Methanol

MPP SYSTEMS

* EIF = Environmental Impact Factor

Produced Water composition

Compounds	ppm
Dispersed oil =	200 - 1,000 (gas)
Dispersed hydrocarbons =	
Dispersed Aliphatics = floating	
Dissolved hydrocarbons Toxic:	
Toxic:	
- Benzene	Aromatics 200 – 3,000
- Toluene	
- Ethyl benzene	
- Xylene	
- PAHs and NPDs	0.2 - 80
- Alkyl Phenols	0.1 - 0.2
Dissolved hydrocarbons Readily Biodegradable	hundreds
Polar:	
- Acids	
- Alcohols (Methanol)	



MPP SYSTEMS

* EIF = Environmental Impact Factor

MPPE effect on EIF

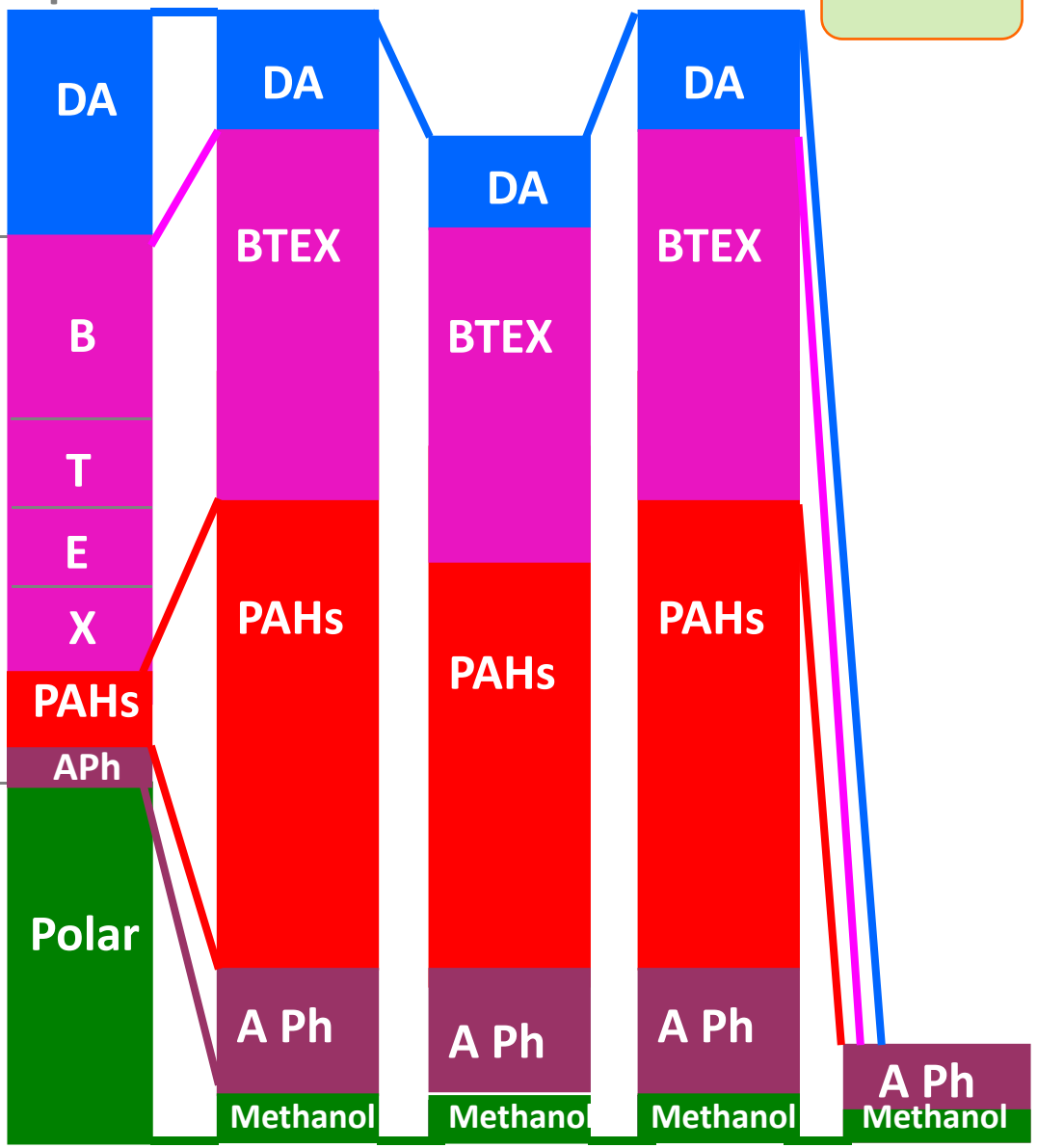
Compounds	ppm	Composition	EIF	"Flotation"	EIF
Dispersed oil =	200 - 1,000 (gas)	DA	DA	DA	DA
Dispersed hydrocarbons =					
Dispersed Aliphatics = floating					
Dissolved hydrocarbons Toxic:		B	BTEX	BTEX	BTEX
Toxic:		T			
- Benzene	Aromatics 200 – 3,000	E			
- Toluene		X			
- Ethyl benzene					
- Xylene					
- PAHs and NPDs	0.2 - 80	PAHs	PAHs	PAHs	PAHs
- Alkyl Phenols	0.1 - 0.2	APh			
Dissolved hydrocarbons Readily Biodegradable Polar:	hundreds	Polar	A Ph	A Ph	A Ph
- Acids			Methanol	Methanol	Methanol
- Alcohols (Methanol)					

MPP SYSTEMS

* EIF = Environmental Impact Factor

MPPE effect on EIF

Compounds	ppm	Composition
Dispersed oil =	200 - 1,000 (gas)	DA
Dispersed hydrocarbons =		
Dispersed Aliphatics = floating		
Dissolved hydrocarbons Toxic:		B
Toxic:		T
- Benzene	Aromatics 200 – 3,000	E
- Toluene		X
- Ethyl benzene		
- Xylene		
- PAHs and NPDs	0.2 - 80	PAHs
- Alkyl Phenols	0.1 - 0.2	APh
Dissolved hydrocarbons Readily Biodegradable Polar:	hundreds	Polar
- Acids		
- Alcohols (Methanol)		



MPP SYSTEMS

* EIF = Environmental Impact Factor

Composition produced water gas / condensate and oil

	Gas produced water	Oil produced water
Flow rates (m^3/h)	< 1 – 150 /180	100 – > 1000
Inlet (ppm)		
Aliphatic HC(dispersed oil)	200 – 1400 (484*)	40 - 100 (15*)
Aromatics (BTEX)	300 – 3000 (482*)	30 – 70 (6*)
PAHs	4 – 80	0.5 – 2
TPH	700 – 4000	> 200
Typical goals	Disp. oil < 10 – 30	Disp. oil < 10 – 30
	BTEX < 10	?
	PAHs < 0.1 – 0.01	?
	TPH < 10 – 30	?
	EIF: Zero Harmful	?

* Shell average offshore data Tekna 2012

MPP SYSTEMS

MPPE

Gas / Condensate and LNG produced water treatment

1. GAS production : produced water after separator /degasser
2. Gas drying (glycol): MEG REGEN Produced water

A. 1 + 2 → MPPE Process removal of:

1.	Dispersed oil (aliphatics)	200 - 1.400 ppm:	> 99%
2.	Dissolved and dispersed aromatics (BTEX)	300 - 3.000 ppm:	> 99%
3.	PAHs	ppm - 4 - 80:	> 99%
4.	Alkyl Phenols	ppb levels:	~ 30%
5.	Chemicals	ppb / ppm:	~ 20 - 50%

B. Onshore, if desired Bio treatment to remove:
Methanol, Glycol, Carboxylic acids, etc.

MPP SYSTEMS

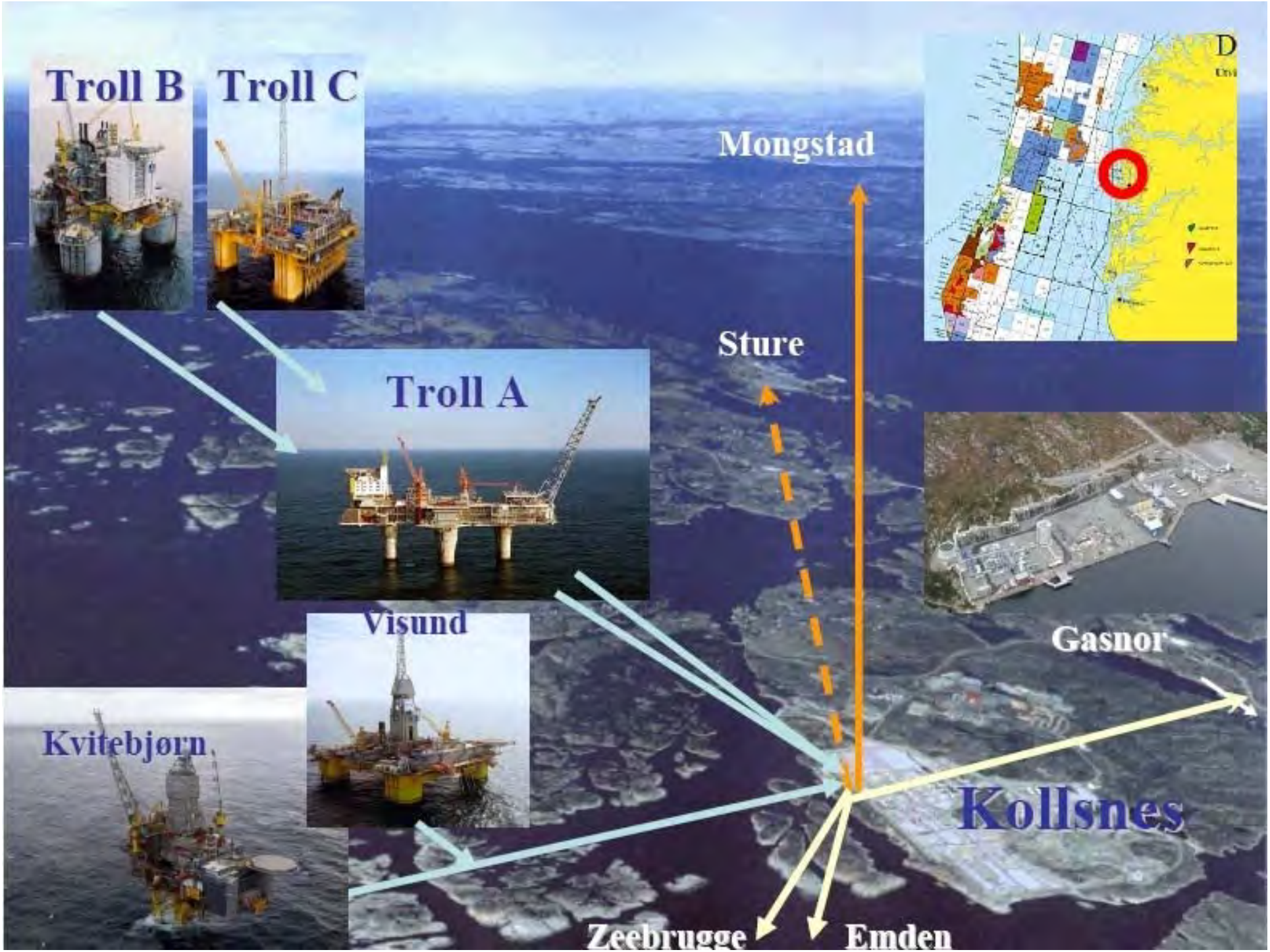
MPPE

New Offshore Tie-ins and impact on On-Shore Facilities Field Case Kollsnes

By Lars Bergersen and Jesper Jacobsson

Statoil

MPP SYSTEMS


Troll B
Troll C
Troll A
Visund
Kvitebjørn
Mongstad
Sture
Gasnor
Kollsnes
Zeebrugge
Emden

Statoil Kollsnes Phenomena

- **Treating offshore Produced Water of 4 platforms** — **Q4 2004**
- **Start up extra platform (Kvitebjørn)**
  - Equal TOC levels! — **Q1 2005**
  - Bioactivity ceased!
- **MPPE installed** — **Q2 2005**
- **Biotreatment recovered within three months** — **Q3 2005**
- MPPE removes
  - Aliphatics (dispersed oil) > 99%
  - BTEX > 99%
  - PAHs > 99%
  - Alkyl Phenols ~ 30%

MPP SYSTEMS

Statoil Kollsnes conclusions

- Equal TOC levels but Bio ceased?
- 20 – 100 times more and varying BTEX contents (up to 600 ppm)
- 10 – 50 times more PAHs and C_2 – C_4 Phenols
- Poisoned biological mass
- BTEX > 12 mg/l could be toxic to biological mass
- Monitoring toxic content (BTEX, PAHs); not TOC

MPPE Statoil Kollsnes

MPPE

- **An MPPE unit was rented May 2005.**

VEOLIA WATER Solutions & Technologies | STATOIL

MPP SYSTEMS

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Statoil Kollsnes (Norway) produced water

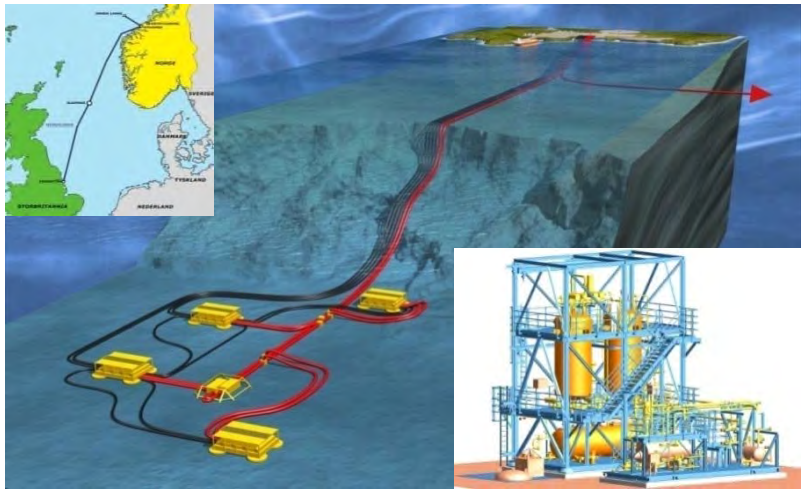
MPP SYSTEMS

MPPE

StatoilHydro / Shell Ormen Lange (Norway) produced water

MPP SYSTEMS

MPPE for Statoil - Shell ORMEN LANGE
Gas Produced Water Treatment



Ormen Lange Project

- World's most challenging gas field development project
- Makes Norway world's largest exporter of natural gas
- Largest industrial project ever carried out in Norway
- 100 kilometer from the northwest coast of Norway

MPPE Unit removes the:

- **Dispersed oil (aliphatics)**
- **Dissolved and dispersed aromatics (BTEX)**
- **Poly Aromatics (PAHs)**

- Flow rate 70 m^3/h
- > 99% removal of BTEX, PAHs, Aliphatics (oil)
- In operation since October 2007

MPP SYSTEMS

Survey Emission Regulations 3/3

- North East Atlantic / North Sea (OSPAR)
  - 1978: 40 ppm dispersed oil (PARCOM)
  - 2007: 30 ppm dispersed oil (OSPAR)

Individual countries

- The Netherlands: Reduction Benzene / Aromatic discharge
  - 1994: Benzene / Aromatic reduction of 80% in 2000
  - 1998: NOGEPA study 55 technologies (MPPE Number 1)
  - 1999: NAM offshore fieldtest L_2 (OTC paper)
  - 2002 / 2003: First commercial offshore MPPE units TOTAL; NAM
- Norway
  - 2002: Zero Harmful Discharge in 2007
  - Environmental Impact Factor (EIF)
- Australia
  - 2007: 50 → 30 ppm dispersed oil
  - 2009: Total Hydrocarbons < 30ppm (dispersed **and dissolved**)
- Egypt
  - 2012: Law 4 (PAHs: "ZERO")

MPP SYSTEMS

Location Pluto LNG Burrup plant

- Burrup, Peninsula, Western Australia

MPP SYSTEMS

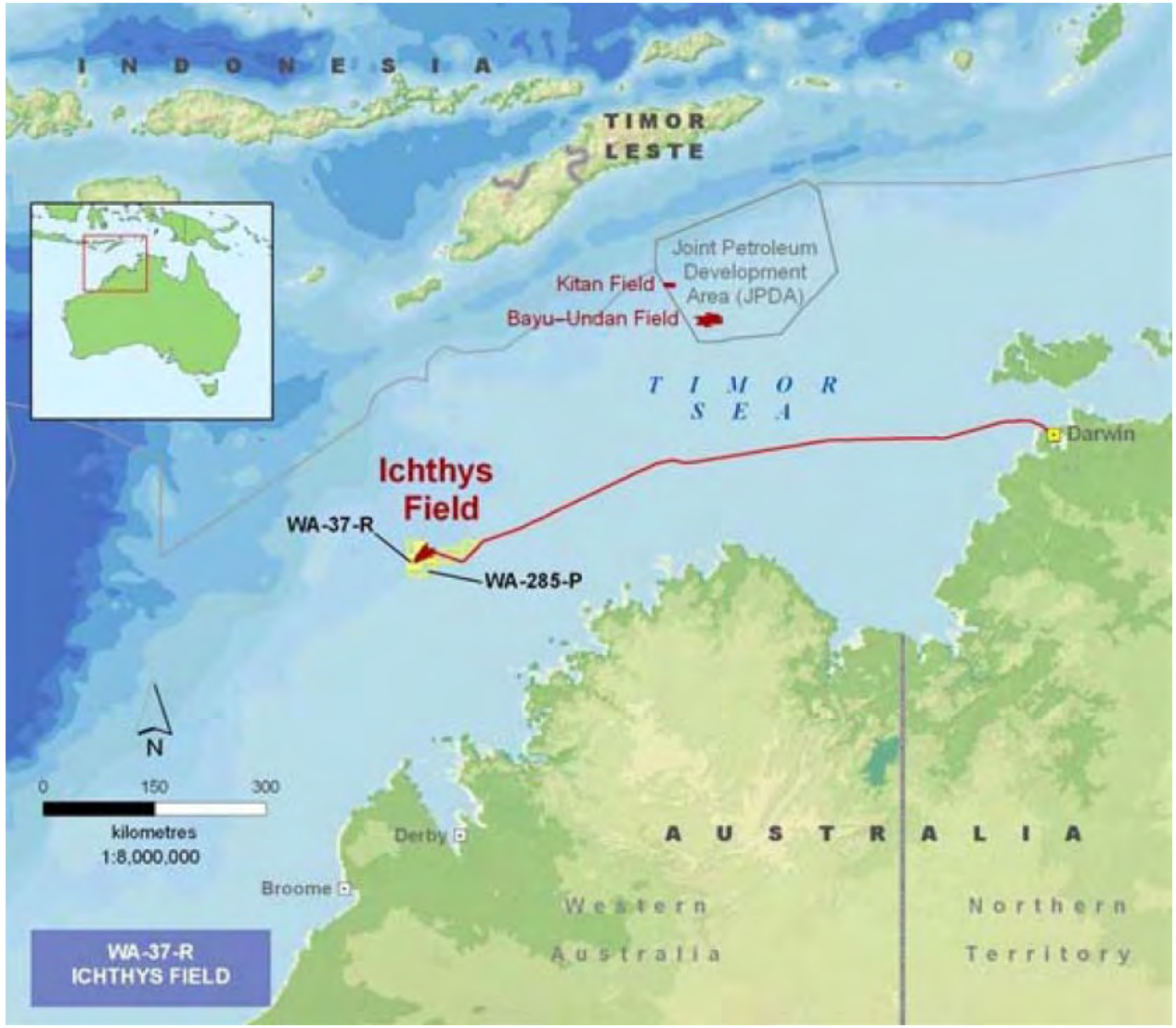
MPPE

Woodside Pluto (Australia) produced water

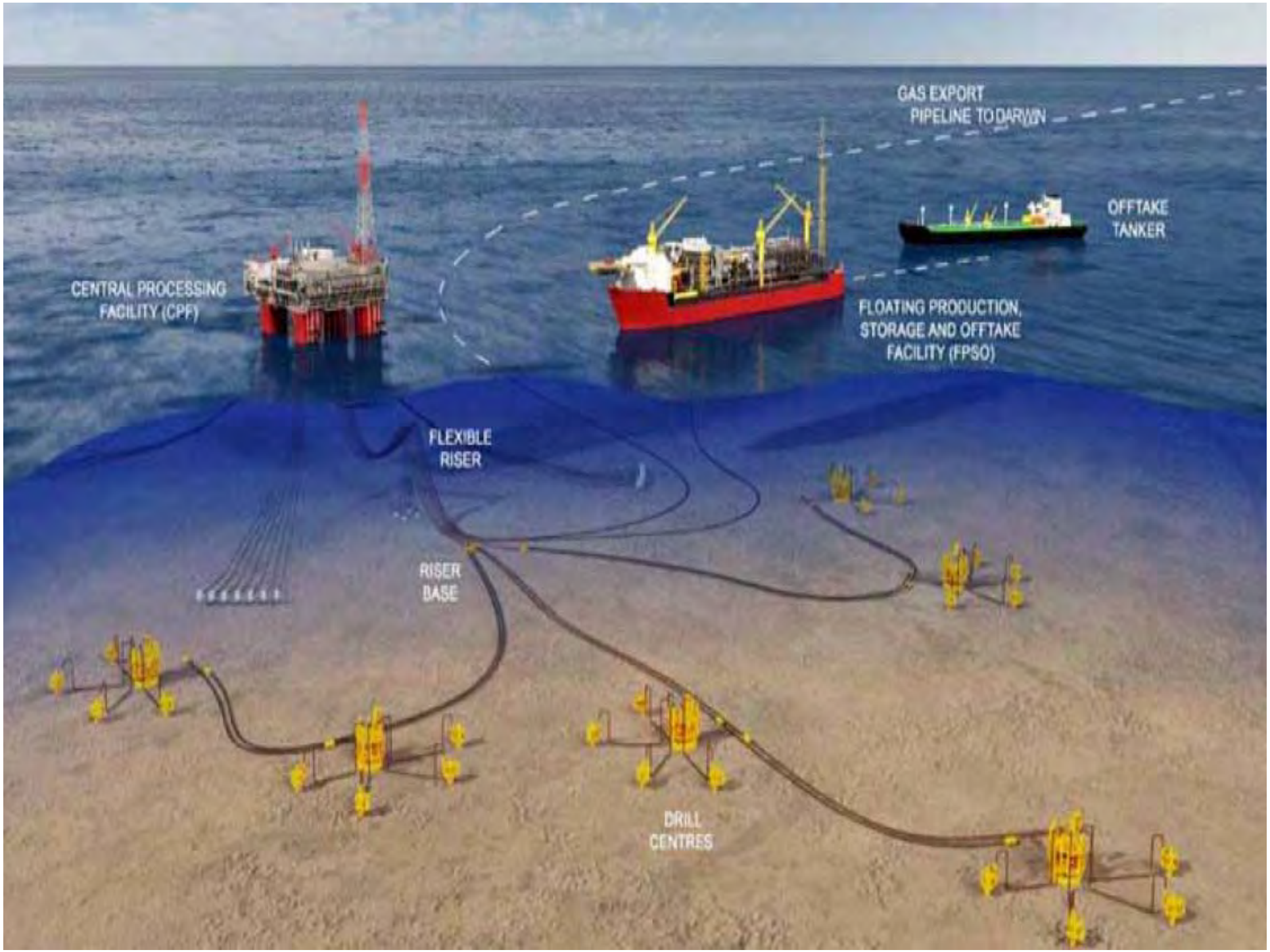
MPP SYSTEMS

MPPE

Inpex Ichthys project



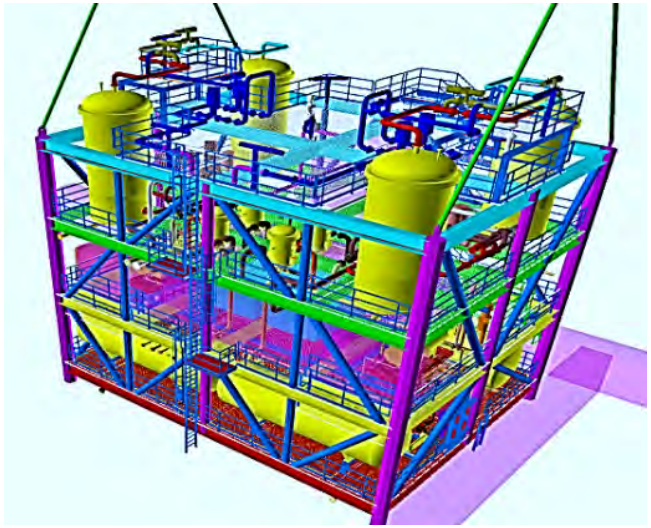
MPP SYSTEMS


GAS EXPORT
PIPELINE TO DARWIN
OFFTAKE
TANKER
CENTRAL PROCESSING
FACILITY (CPF)
FLOATING PRODUCTION,
STORAGE AND OFFTAKE
FACILITY (FPSO)
FLEXIBLE
RISER
RISER
BASE
DRILL
CENTRES

MPPE

Inpex Ichthys

MPPE unit



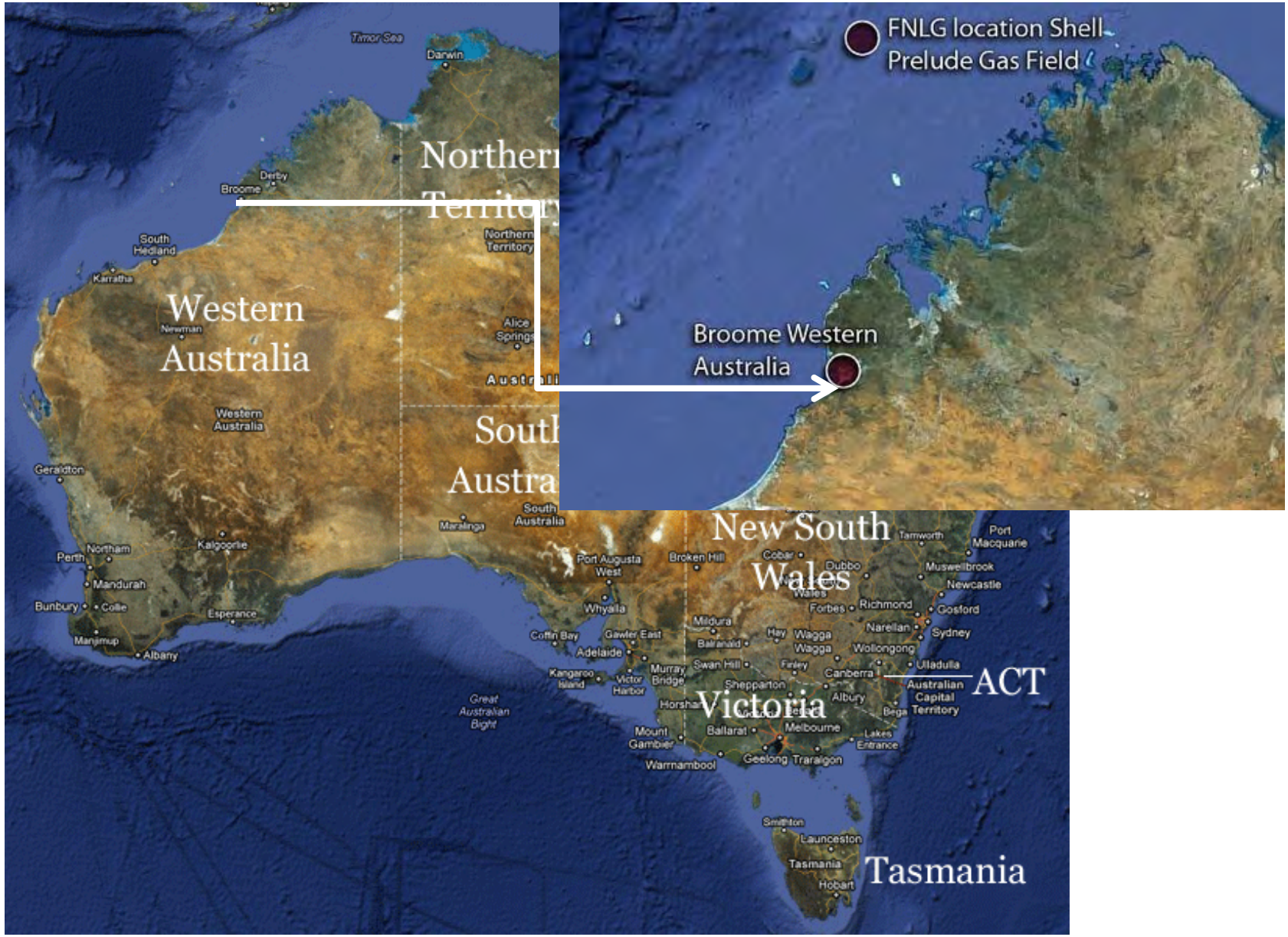
MPPE unit

MPP SYSTEMS

Contents presentation

Why MPPE for FLNG?

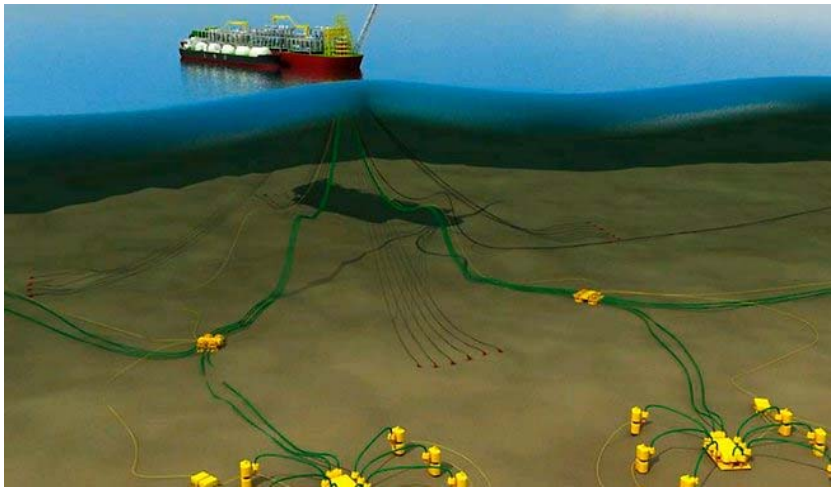
MPP SYSTEMS


FNLG location Shell
Prelude Gas Field
Broome Western
Australia
Western
Australia
Northern
Territory
South
Australia
New South
Wales
Victoria
ACT
Australian
Capital
Territory
Tasmania
Timor Sea
Darwin
Broome
Derby
South
Hedland
Karratha
Newman
Alice
Springs
Geraldton
Perth
Northam
Kalgoorlie
Mandurah
Bunbury
Collie
Esperance
Manjimup
Albany
Western
Australia
Maralinga
South
Australia
Port Augusta
West
Broken Hill
Whyalla
Coffin Bay
Gawler East
Adelaide
Kangaroo
Island
Victor
Harbor
Murray
Bridge
Great
Australian
Bight
Mount
Gambier
Warrnambool
Geelong
Ballarat
Melbourne
Traralgon
Lakes
Entrance
Shepparton
Swan Hill
Mildura
Hay
Balranald
Wagga
Wagga
Forbes
Cobar
Dubbo
Tamworth
Port
Macquarie
Muswellbrook
Newcastle
Richmond
Gosford
Narellan
Sydney
Wollongong
Ulladulla
Canberra
Albury
Bega
Farley
Smithton
Launceston
Tasmania
Hobart

MPP SYSTEMS

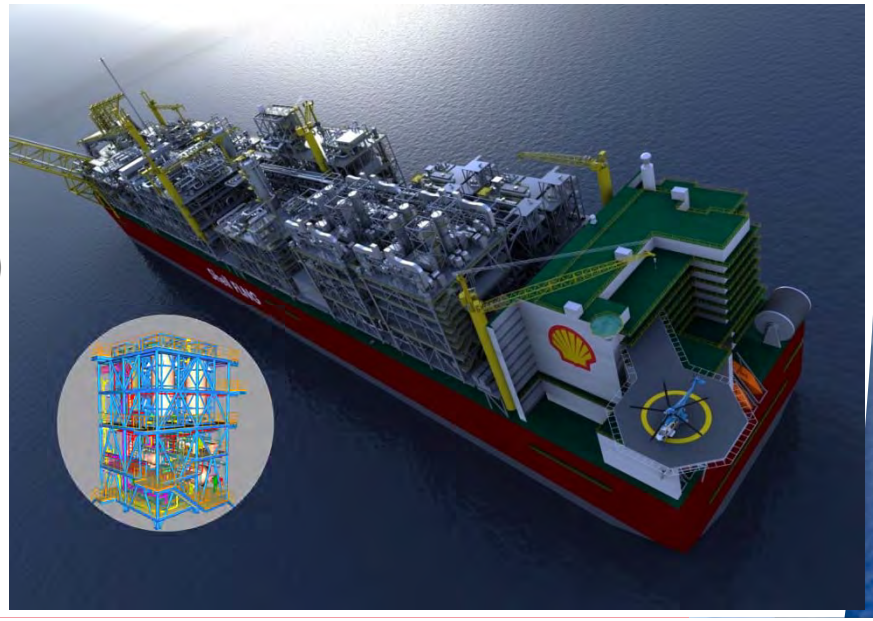
MPPE

MPPE unit for first Floating LNG plant in the world; Shell Prelude - Australia



Shell Prelude project

- First Floating LNG plant in the world
- FLNG technology reduces project costs and the environmental footprint of an LNG development
- Delivery April 2013
- Direct discharge after MPPE treatment



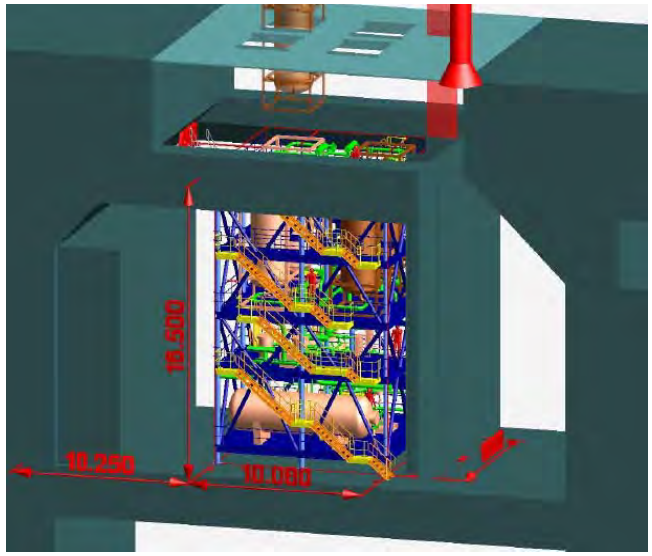
MPPE for removal of:

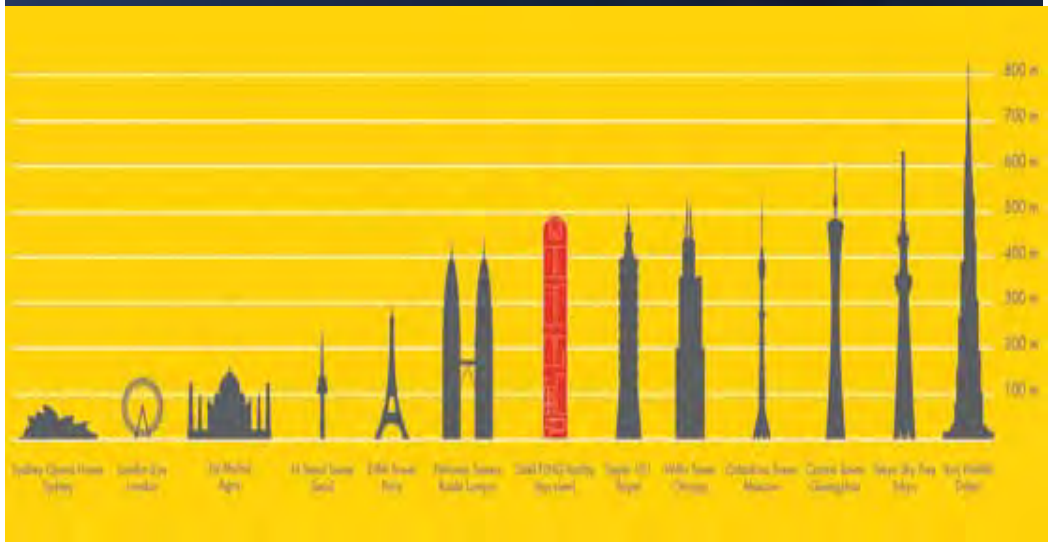
- Dissolved and dispersed oil (aliphatics
- Dissolved and dispersed aromatics (BTEX)
- Poly Aromatic Hydrocarbons (PAHs)
- Flowrate: 140 m^3/h
- Removal of BTEX, PAHs, Aliphatics (oil)

MPP SYSTEMS

Shell Prelude Floating LNG

- Treatment + liquefaction
- 488m x 74m:
  largest floating structure
- Avoids: pipelines, coastal modifications, land use
- Lower environmental footprint
- Flexibility to relocate and reuse
- For “stranded” gas assets
- A game changer





MPP SYSTEMS


SHELL FLNG

MPPE

Shell Prelude MPPE unit

MPP SYSTEMS

MPPE

Shell Prelude MPPE unit

MPP SYSTEMS

MPPE

“Why MPPE for FLNG”

- Removal of toxic content (Oil, BTEX) for Zero Harmful Discharge
- Separation performance independent of inlet concentration (peak loads!)
- Robust against water environment (surfactants, inhibitors, chemicals)

- Recovered hydrocarbons ready for use as a product
- 100% Recovery of separated hydrocarbons and water
- No waste stream
- Remote controlled

MPP SYSTEMS

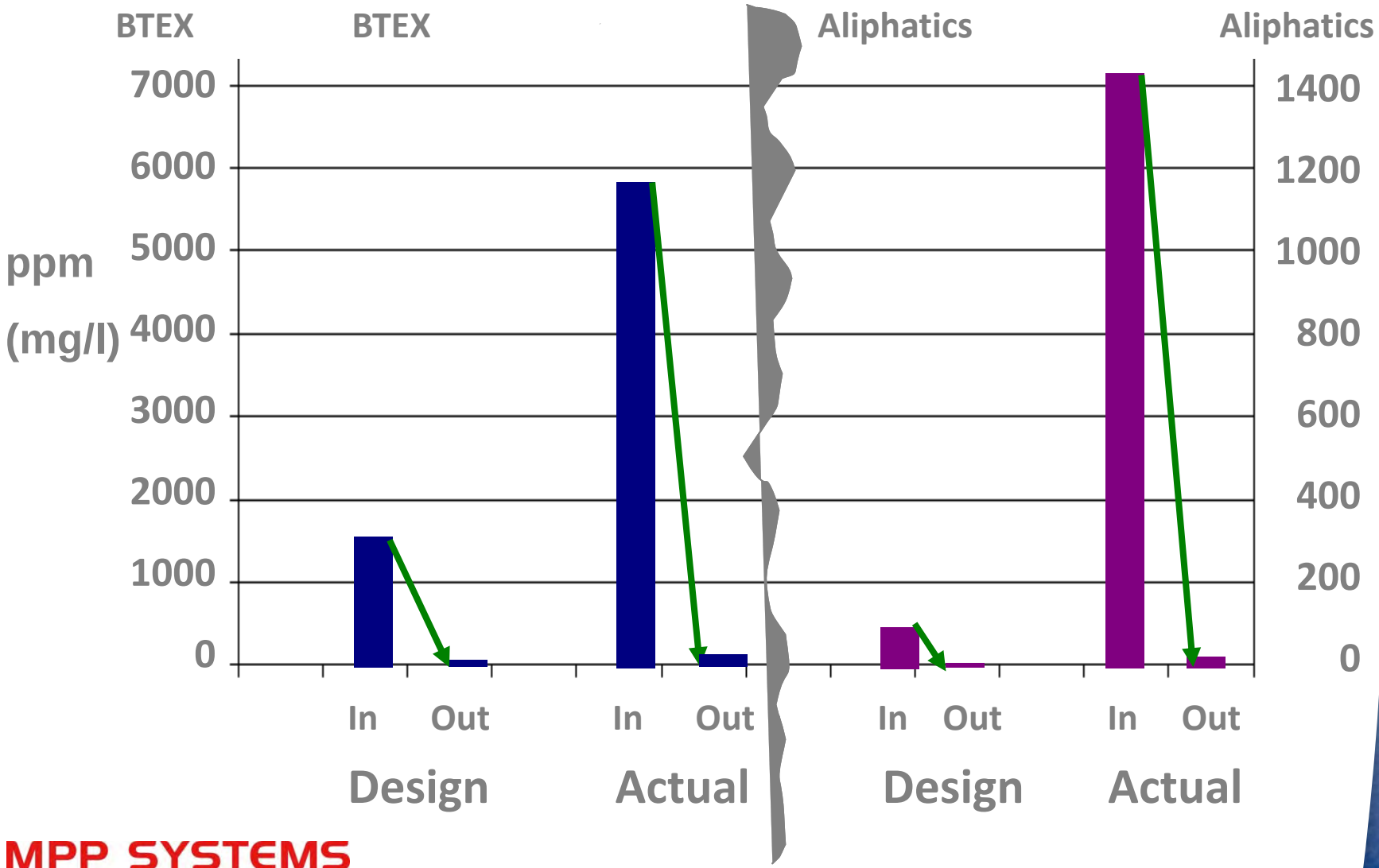
MPPE performance in offshore produced water

	Influent levels ppb	Removal %
Gas / Condensate / LNG		
BTEX (dissolved/dispersed)	300,000 – 3,000,000	> 99%
Aliphatics (dispersed oil)	100,000 – 1,300,000	> 99%
PAHs	200 – 80,000	> 99%
Alkyl Phenols	14,000	~ 30%
Field chemicals, inhibitors	ppm levels	20 – 50%
Environmental Impact Factor		95 – 99%
Oil (Total, NAM, StatoilHydro)		
BTEX	30,000 – 70,000	> 99%
Aliphatics (dispersed oil)	13,500 – 40,000	80 – 95%
PAHs	500 – 2,100	> 99%
Alkyl Phenols	ppb levels	~ 30%
Environmental Impact Factor		> 85%

MPP SYSTEMS

MPPE

MPPE Robustness (1) Design / Actual

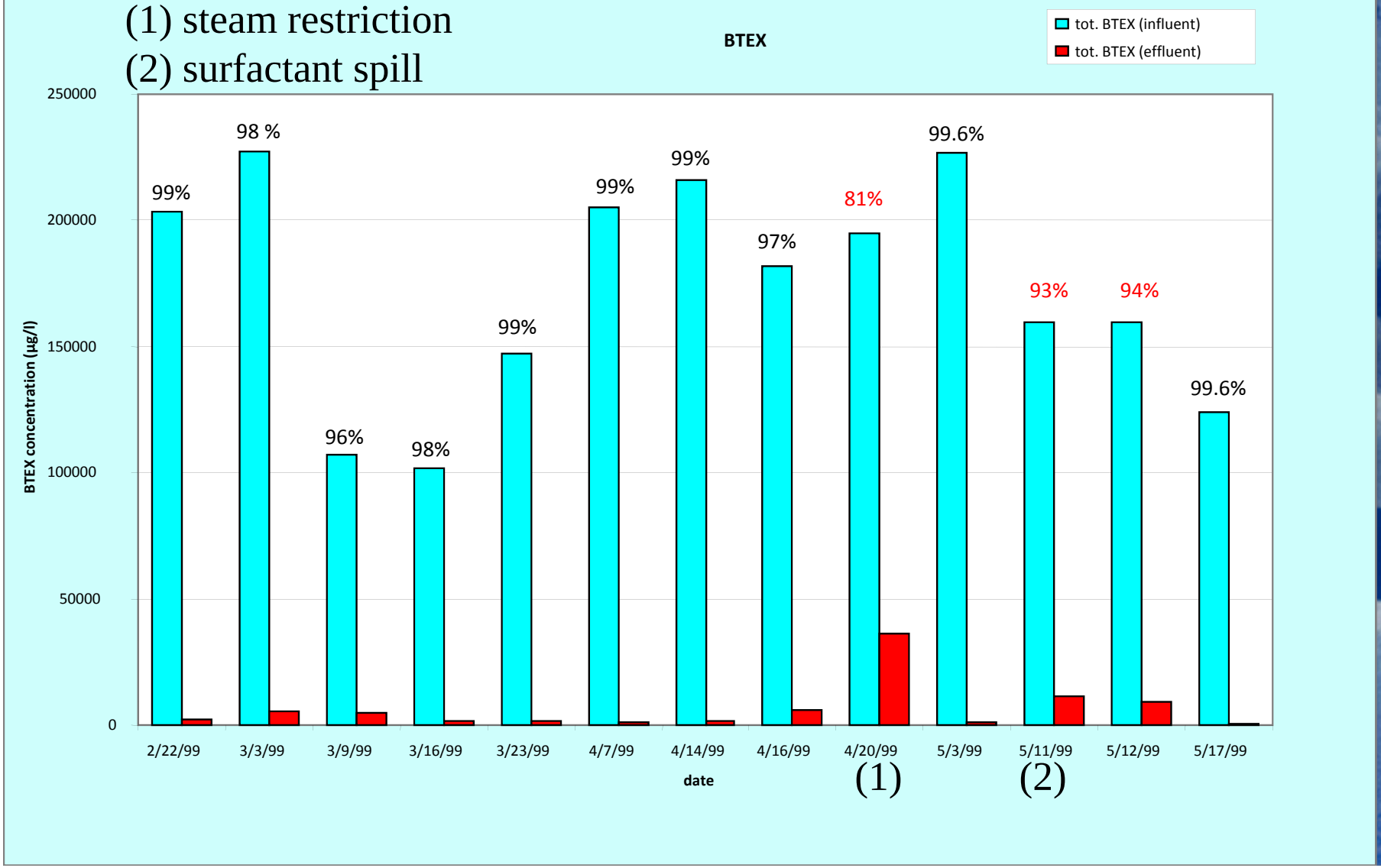


MPP SYSTEMS

MPPE

MPPE robustness (2): Surfactants (NAM)

(1) steam restriction
(2) surfactant spill



MPPE

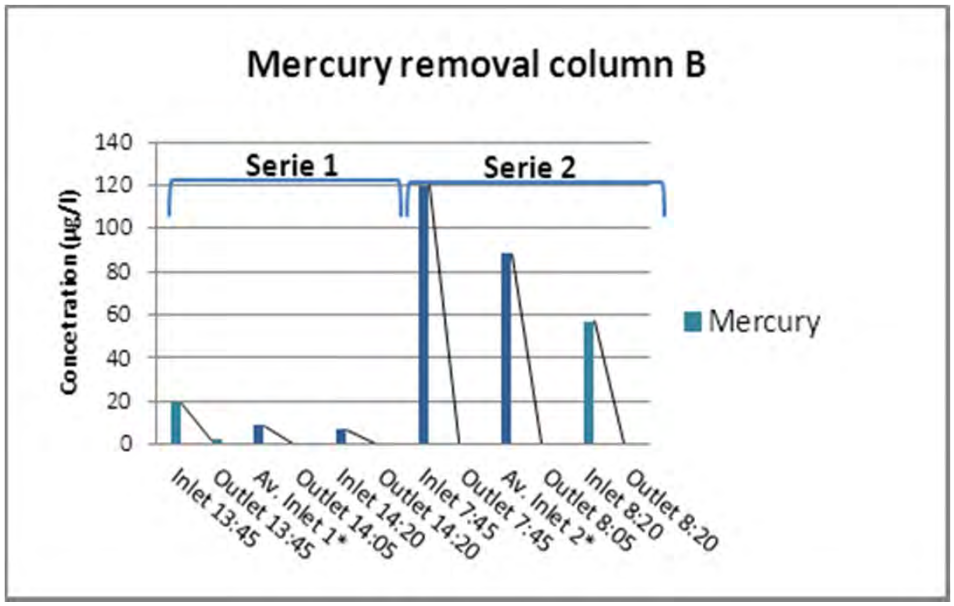
Contents presentation

MPP SYSTEMS

MPPE

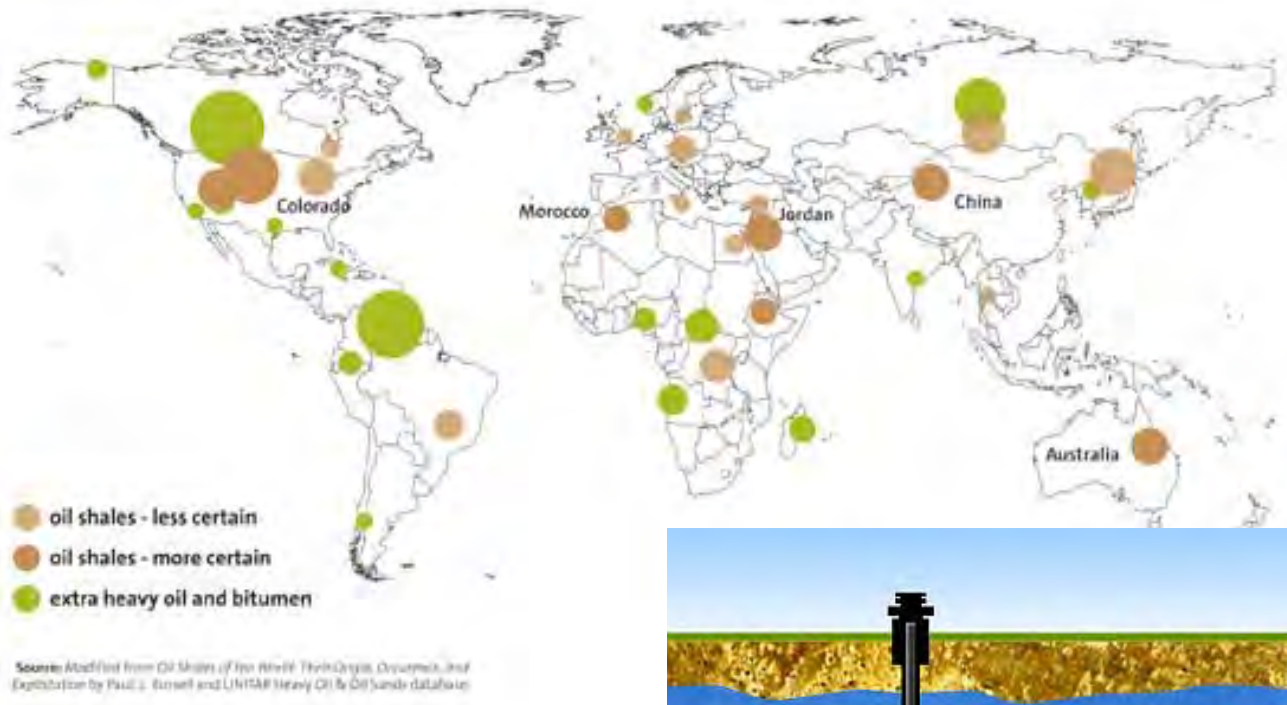
MPPE observed Mercury Removal

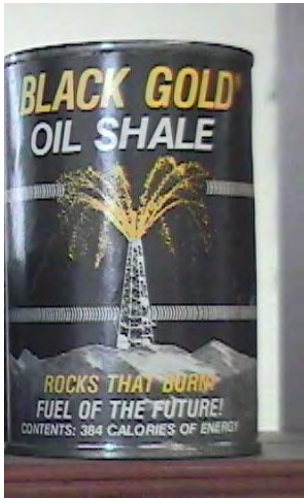
- NAM offshore field test 1999 (OTC paper)
- Bench Mark studies 2011
- Cadmium, lead, nickels : 0.0001 – 0.014 ppb
- Mercury inlet : 3 – 120 ppb
- Cases with removal %
  a. 5 years: 81 – 85 %
  b. 8 years: > 92%
  c. 9 years: 98 – 99.0 %
  d. 10 years: 83 – 98 %

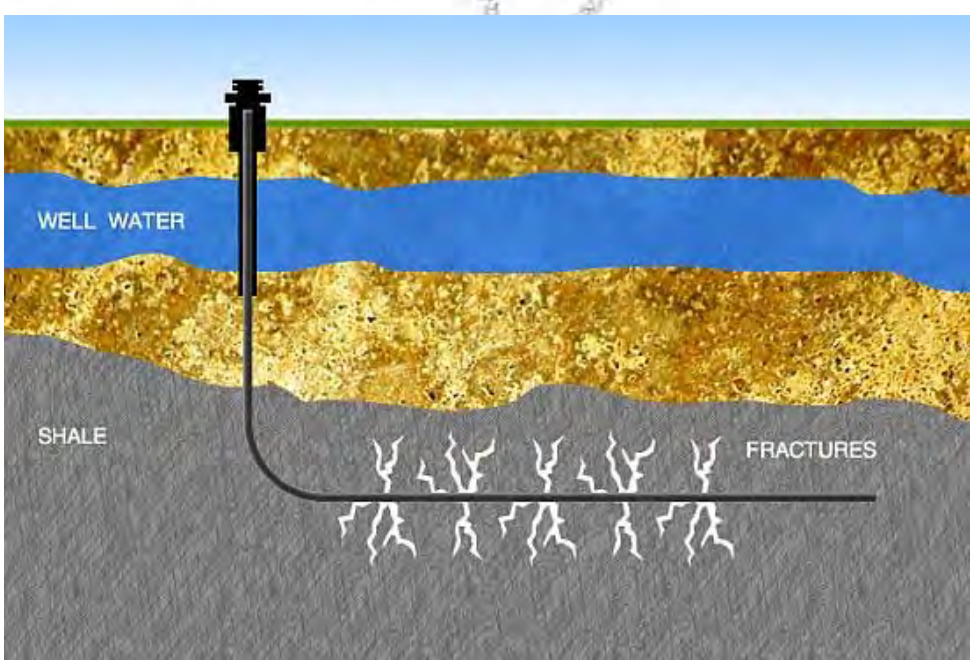


MPP SYSTEMS

Future MPPE: Shale oil

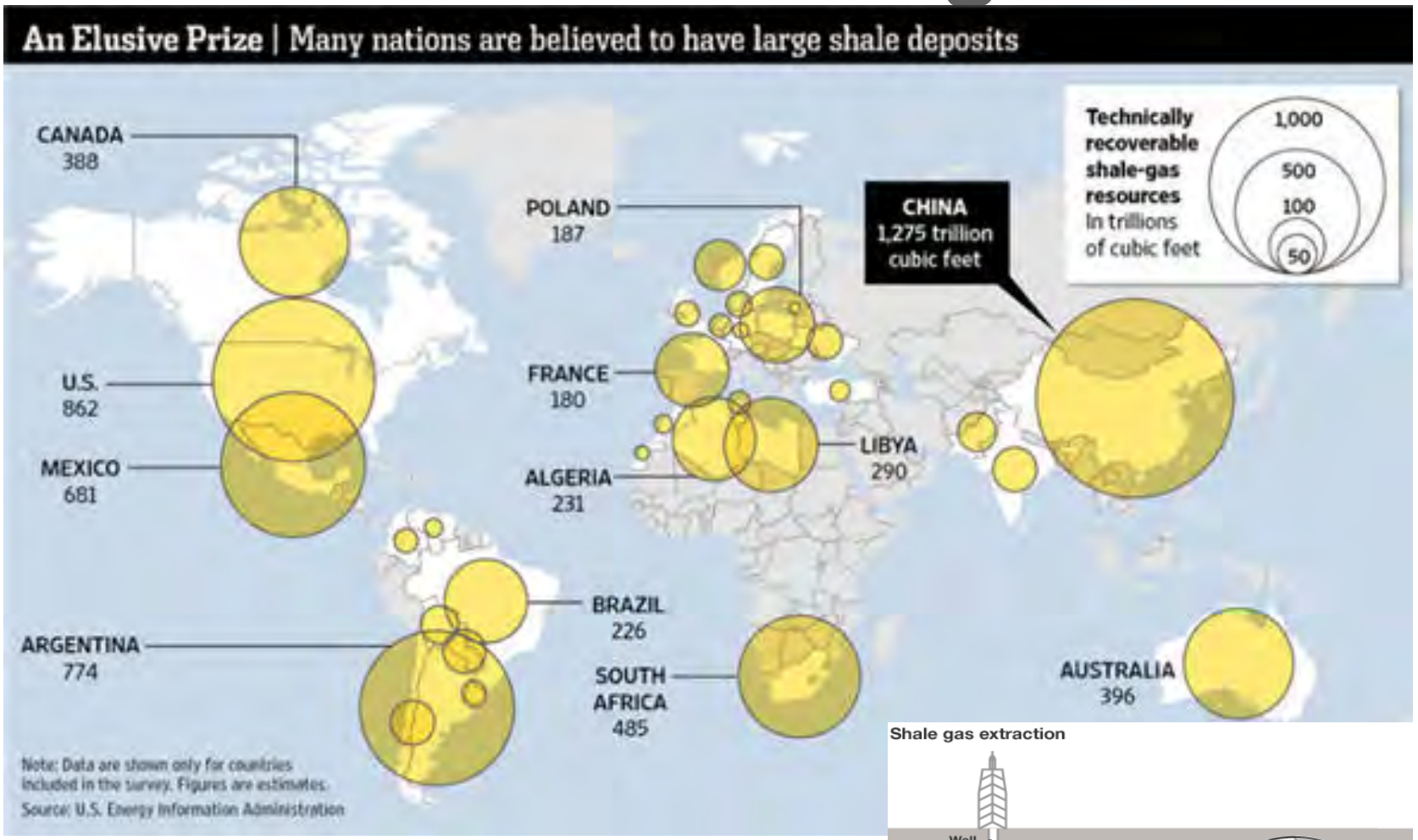


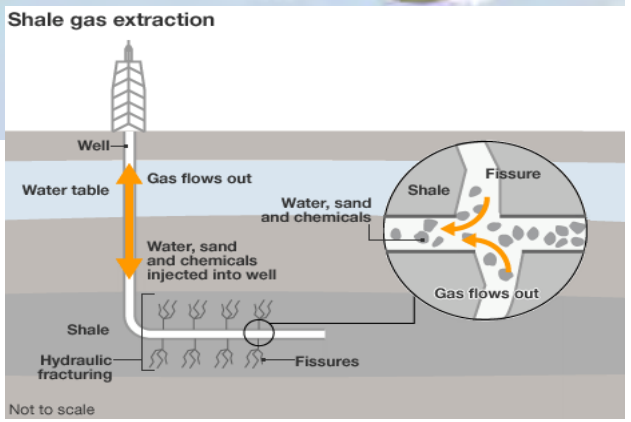




MPP SYSTEMS

Future MPPE: Shale gas





MPP SYSTEMS

Shell Prelude MPPE unit

Questions?

MPP SYSTEMS