Hydranautics – Nitto
Membrane Applications, Case Studies, Lessons Learnt
Basic Facts

• Nitto dates back to 1918
• Hydranautics founded in 1963
• 1987 merged with Nitto
• 32,000 employees worldwide
• 750,000 milions of yen turnover
• 4% of turnover dedicated to R&D

The Nitto Group now operates 109 companies in 29 different countries worldwide.
Nitto Group offers some 13,500 products to approx 70 industries. Ind materials based on the high-polymer synthesis & adhesive processing tech.

Our technology is everywhere... INCOG-NITTO

Automotive Products
- Body Panel-reinforcing & Vibration-damping Material
- Surface Protection Film for Automobiles
- High-functional Vibration-damping Material
- Optical Film for LCD
- Transparent Conductive Film
- Thin-film Metal Circuit Board for Magnetoresistive Head
- Porous Filtration Membrane
- Surface Protection Film for Electronics & Optical Components
- Thermal Release Tape

Electronics-related Products
- Optical Film for LCD
- Transparent Conductive Film
- Thin-film Metal Circuit Board for Magnetoresistive Head
- Porous Filtration Membrane
- Surface Protection Film for Electronics & Optical Components
- Thermal Release Tape

Industrial Products
- Porous Filtration Membrane
- Thermal Release Tape

Housing & Construction-related Products
- Waterproofing & Airtight Tape
- Flooring Protection Tape
- Waterproofing & Airtight Tape for Irregular Surfaces

Elements for pressure membrane processes
- Reverse Osmosis Membrane Element for Water Desalination
- Selection of membrane elements for various industries
- Sanitary membranes for Process Separation
- Transdermal Therapeutic Patches
- Cultured Ginseng Concentrates
- Surgical Tapes and Dressings
- Waterproofing & Airtight Tape
- Flooring Protection Tape
- Waterproofing & Airtight Tape for Irregular Surfaces

Healthcare Products
- Transdermal Therapeutic Patches
- Cultured Ginseng Concentrates
- Surgical Tapes and Dressings
- Waterproofing & Airtight Tape
- Flooring Protection Tape
- Waterproofing & Airtight Tape for Irregular Surfaces

Our technology is everywhere... INCOG-NITTO
2002 Membrane assembly plant start in Shanghai, China

1973 R&D of separation membrane start
1986 RO/UF plant start in Shiga, Japan
1987 Hydranautics joins Nitto Denko

Shanghai CHINA

Singapore R&D center

Shiga JAPAN

Headquarters Oceanside, USA
Hydranautics Offers Integrated Membrane Solutions®

CPA
Composite PolyAmide
Proven Brackish Membranes
Highest Rejection

ESPA
Energy Saving PolyAmide
Low Pressure

Hydranautics Offers Integrated Membrane Solutions®

Separation Process
Dairy, Food & Beverage

ESNA / NANO / HYDRACoRe
Nano Filtration

SWC
SeaWater Composite

HYDRAcap®/HYDRAsub®
UF/MF Capillary Technology

LFC
Low Fouling Composite

Nitto Group Company
HYDRAcore® - Color Removal

- **HYDRACoRe10** is rated at approximately 3,000 Daltons
  - Rejection profile: 10-15% of NaCl, 4% of glucose, and 15% of sucrose
- **HydraCoRe50** is rated at approximately 1,000 Daltons
  - Rejection profile: 50-60% of NaCl, 18% of glucose, and 41% of sucrose

- pH of 2-11 Operating and 1-12 for Cleaning
- Max continuous chlorine conc: 10 PPM
- Max chlorine conc. for cleaning: <100 ppm
HYDRACoRe 10 and 50 for Color Removal on highly colored food streams

### Soy Sauce

<table>
<thead>
<tr>
<th>Feed</th>
<th>Color Units</th>
<th>Rej %</th>
<th>Color Units</th>
<th>Rej %</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCore10</td>
<td>44380</td>
<td>71.3</td>
<td>57840</td>
<td>75.1</td>
</tr>
<tr>
<td>HCore50</td>
<td>12,740</td>
<td>97.2</td>
<td>950</td>
<td>98.4</td>
</tr>
</tbody>
</table>

### Grape Juice

<table>
<thead>
<tr>
<th>Feed</th>
<th>Color Units</th>
<th>Rej %</th>
<th>Color Units</th>
<th>Rej %</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCore10</td>
<td>458</td>
<td>901</td>
<td>4610</td>
<td>87.6</td>
</tr>
<tr>
<td>HCore50</td>
<td>80</td>
<td>96.5</td>
<td>2282</td>
<td>15.2</td>
</tr>
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</table>

### Red Wine (Alcohol)

<table>
<thead>
<tr>
<th>Feed</th>
<th>Color Units</th>
<th>Rej %</th>
<th>Color Units</th>
<th>Rej %</th>
<th>Brix</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCore10</td>
<td>458</td>
<td>901</td>
<td>4610</td>
<td>92.4</td>
<td>7</td>
</tr>
<tr>
<td>HCore50</td>
<td>72</td>
<td>98.4</td>
<td>72</td>
<td>99.6</td>
<td>5.8</td>
</tr>
</tbody>
</table>
HYDRACoRe 10 and 50 for color removal on highly colored food streams

### Black Tea

<table>
<thead>
<tr>
<th>Feed</th>
<th>Abs 408 Color Units</th>
<th>Rej %</th>
<th>Abs 456 Color Units</th>
<th>Rej %</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCore10</td>
<td>202</td>
<td>95.3</td>
<td>136</td>
<td>96.4</td>
</tr>
<tr>
<td>HCore50</td>
<td>15</td>
<td>99.7</td>
<td>8.9</td>
<td>99.8</td>
</tr>
</tbody>
</table>

### Coffee

<table>
<thead>
<tr>
<th>Feed</th>
<th>Abs 408 Color Units</th>
<th>Rej %</th>
<th>Abs 456 Color Units</th>
<th>Rej %</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCore10</td>
<td>2166</td>
<td>85.7</td>
<td>1637</td>
<td>90.6</td>
</tr>
<tr>
<td>HCore50</td>
<td>231</td>
<td>98.5</td>
<td>139</td>
<td>99.2</td>
</tr>
</tbody>
</table>
HYDRAcore® - Pulp and Paper WWT

Pulp

Pulp Bleaching

Purified Pulp

Waste water w/ Bleach

CAN NOT discharge directly
CAN NOT treat general NF/RO because of Bleach

…. Waste Water Treatment cost is very High
**HYDRAcore® - PILOT**

- **Recovery**: 50 to 90%
- **Feed Color**: 3K–12K PCU
- **pH**: 10.2
- **Design Flux**: 24.5 m³/d
- **Permeate Color**: < 50 PCU

**HYDRAcap** → **HYDRACoRe50**

<table>
<thead>
<tr>
<th></th>
<th>UF Feed</th>
<th>UF Filtrate &amp; NF Feed</th>
<th>NF Permeate</th>
<th>Softened City</th>
</tr>
</thead>
<tbody>
<tr>
<td>TDS (mg/l)</td>
<td>2,345</td>
<td>1,928</td>
<td>973</td>
<td>338</td>
</tr>
<tr>
<td><strong>Color (PCU)</strong></td>
<td><strong>12,000</strong></td>
<td><strong>12,000</strong></td>
<td><strong>20</strong></td>
<td><strong>10</strong></td>
</tr>
<tr>
<td>TOC (mg/l)</td>
<td>580</td>
<td>530</td>
<td>53</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>TSS (mg/l)</td>
<td>8.7</td>
<td>&lt; 5</td>
<td>&lt; 5</td>
<td>&lt; 5</td>
</tr>
</tbody>
</table>
DAIRY - Whey Processes

Effluent from Cheese Plant
✓ BOD reduction
✓ Valuable Substances Recovery

- UF Spirals
  - Cheese Whey
    - 1% Whey Protein
    - 5% Lactose
    - 0.5% Ash
  - UF Permeate
    - 5% Lactose
    - 0.5% Ash

- RO Spirals
  - UF Permeate
  - UF Spirals
  - RO Spirals
  - Permeate
    - 500-1200 BOD
  - RO Permeate
  - Lactose
    - 20% Lactose
    - 2% Ash

- Polished Water
  - For Reuse

- Dairy 5/10K
- DairyRO
- DairyNF
- Hydropolish-8
- SanRO HS-8
## HYDRAcap® MAX Overview

<table>
<thead>
<tr>
<th>Feature</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow path</td>
<td>Outside to inside</td>
</tr>
<tr>
<td>Membrane material</td>
<td>PVDF</td>
</tr>
<tr>
<td>Filtration mode</td>
<td>Dead end or cross-flow</td>
</tr>
<tr>
<td>Membrane configuration</td>
<td>Hollow fiber</td>
</tr>
<tr>
<td>Membrane area*</td>
<td>97 ft² (9 m²) / 560 ft² (52 m²) / 840 ft² (78 m²) / 1130 ft² (105 m²)</td>
</tr>
<tr>
<td>Module Height*</td>
<td>45” / 54” / 72” / 92” (1.1 / 1.4 / 1.8 / 2.3 m)</td>
</tr>
<tr>
<td>Module Diameter</td>
<td>10” (250 mm)</td>
</tr>
<tr>
<td>Fiber ID/OD</td>
<td>0.6/1.2 mm</td>
</tr>
<tr>
<td>Pore size</td>
<td>0.08 µm (Ultrafiltration)</td>
</tr>
<tr>
<td>Physical cleaning mode</td>
<td>Air scour</td>
</tr>
</tbody>
</table>

* HYDRAcap® MAX 4040 / HYDRAcap® MAX 40 / HYDRAcap® MAX 60 / HYDRAcap® MAX 80
Feed is treated with FeCl₃/NaOH/Polyelectrolyte

Permeate reuse as process water
Olive Oil Waste Water

UF performance system

**UF system information:**
- Start-up: December 2014
- Water source: OMW
- Production: 20 m3/h
- Water temperature: 16 degC
- 1 racks of 6 HYDRAcapMAX60

**Operating conditions:**
- Filtration flux: 30-38 Lmh
- Filtration time: 20 min
- Operating TMP: 0.8 to 1.2 bar
- Hydraulic recovery: 81%

**Quality achievement:**
- Feed turbidity: 40-60 NTU

**Chemical usage:**
- MC1/MC2 frequency: 1 day (NaOH, NaClO)
- MC3 frequency: 1 day (H₂SO₄)
Potable Water Application - Croatia

Feed water source: Surface water  
Pretreatment: 200 um strainer  
UF Capacity: 400 m3/h - 2 racks of 34 HYDRAcapMAX60

Feed water characteristics:
- No inlet coagulation
- Dead end mode
- Feed turbidity: 1 to 50 NTU
- Temp.: 1 to 20 degC
- COD 10 ppm

Operating parameters:
- Filtration time 40 mins below 20 NTU and 20 mins above 20 NTU
- Maximum flux 75 Lmh
- Maintenance cleans with filtrate
- One MC1/2 per day (caustic/chlorine)
  One MC3 per day (sulphuric acid)
Potable Water Application - Croatia

The problem: Existing potable water plant with turbidity and bacteria issue
The solution: Upgrade from existing sand filters to UF system

**BENEFITS:**
- Total elimination of bacteria with implementation of HYDRAcapMAX modules
- Constant permeate turbidity independent of feed solid load
Industrial waste water - Taiwan

- **Water source:** Silicon wafer production industry – Dicing and backgrinding operations
- **Operating parameters:**
  - 8 HYDRAcapMAX 60 (78 m²)
  - 10% cross flow
  - No inlet coagulation
  - On line chlorination (0.2 ppm)
  - Maintenance cleans with filtrate
  - Two MC1 per day

**Start-up date:** June 2012

**Reuse Application:** Feed for Ultrapure Water Treatment System

**Expansion:** 5 references in total in Taiwan and China
Industrial waste water - Taiwan

Performance of the plant:
- Filtration flux: 35 LMH
- Filtration time: 25 min
- Hydraulic recovery 85%
- Two Caustic Cleaning per day

Feed water  Turbidity = 1100 NTU

Permeate water  <0.1 NTU
UF-RO Tertiary Sewage Effluent Plant in UAE

Location: Dubai, near Burj Khalifa

Feed water source: Treated Sewage Effluent

Application: District Cooling

Capacity: 26,800 m3/day

Commissioning: September 2014

UF Design: 8 x 33 HYDRAcap MAX 80

RO Design: 1,176 ESPA2-LD
UF quantitative and qualitative data

**Typical UF feed water quality:**

- Turbidity: 2-3 NTU
- Total Suspended Solids: 5 ppm
- BOD: 5 ppm
- COD: 20 ppm
- pH: 6.5
- Temperature: 20 to 35 degC

**Typical UF permeate water quality:**

- Turbidity: 0.1 NTU
- SDI: 2

**Operating conditions:**

- Filtration time: 45 mins
- Filtration flux: 25 to 30 Lmh (Design 50 Lmh)
- MC1+2 frequency: Every 20 cycles (15-16 hrs)
- MC3 frequency: Every 5 days
- CIP frequency: None since start-up
- Feed pressure: 2.5 to 3 bar
Cooling Tower Blowdown - UAE

• Cooling tower blow down → lamellar clarifier (dosage of polymer) → 10 HYDRAcap MAX 60 → Iron removal filter → RO

• System capacity = 1,000 m³/day
• No backwash / Only Air scour
• Flux = 70 l/mh
• Operating Sequence
  • Filtration time: 25 min
  • Chlorine MC: 1/day
    • 200 ppm NaOCl
  • Acid MC: 2/week
    • 1470 ppm H₂SO₄ (pH ~2)
Feed water vs Permeate water
Feed turbidity 50 NTU
Permeate turbidity < 1 NTU

Waste water from Air Scour sequence

Air connections to each module

Operating pressure: 2 bar
Operating TMP: 0.8 to 1.2 bar
HYDRAsub®-ES MBR Technology

**HYDRAsub® Overview**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application</td>
<td>Membrane Bioreactor</td>
</tr>
<tr>
<td>Process Configuration</td>
<td>Submerged</td>
</tr>
<tr>
<td>Filtrate flow path</td>
<td>Outside to inside</td>
</tr>
<tr>
<td>Membrane material</td>
<td>PVDF</td>
</tr>
<tr>
<td>Membrane configuration</td>
<td>Vertical, Hollow fiber</td>
</tr>
<tr>
<td>Primary Cleaning Method</td>
<td>Air Scour</td>
</tr>
</tbody>
</table>

**Key Advantages**

- High flux operation
- Low footprint requirement
- Simple operating process
- Durable construction
HYDRAsub®-ES MBR Technology

- Filtrate Adapters
- HYDRAsub® Element
- Cage
- Air Diffuser
## Typical Operating Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Typical Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Operating Flux(^1,2)</td>
<td>gfd (LMH)</td>
<td>19.6 (33)</td>
</tr>
<tr>
<td>Peak Operating Flux(^1,2)</td>
<td>gfd (LMH)</td>
<td>30 (51)</td>
</tr>
<tr>
<td>Transmembrane Pressure (TMP)</td>
<td>psi (kPa)</td>
<td>2-4 (13.8-27.6)</td>
</tr>
<tr>
<td>Mixed Liquor Suspended Solids (MLSS) concentration in membrane tank</td>
<td>mg/L</td>
<td>8,000-12,000</td>
</tr>
<tr>
<td>Filtrate Turbidity</td>
<td>NTU</td>
<td>&lt; 0.2</td>
</tr>
<tr>
<td>Filtrate Total Coliform</td>
<td>cfu./100 mL</td>
<td>&lt; 5</td>
</tr>
<tr>
<td>Filtrate TSS</td>
<td>mg/L</td>
<td>&lt; 2</td>
</tr>
<tr>
<td>Filtrate SDI</td>
<td></td>
<td>&lt; 3</td>
</tr>
</tbody>
</table>

\(^1\)For municipal applications, at 20 deg C  
\(^2\)Piloting recommended to optimize flux for industrial applications
HYDRAsub® MBR Applications

• Domestic Wastewater
  – Municipalities
  – Hotels, Apartment complexes
  – Grey Water

• Industrial Wastewater
  – Food Industry – Beer, Dairy, etc.
  – Automobile Production
  – Oil Refineries
  – Chemical Production
  – Potentially any wastewater with significant biological activity
Jurong WRP, Singapore

- Municipal Singapore Public Utilities Board (PUB) decided to upgrade Phase 1 of the existing Jurong Water Reclamation Plant with a 68,000 m³/day (18 MGD) MBR
- Jurong WRP has 3 Phases, which treat wastewater from 5 nearby pump stations
  - Phase 1 (MBR) treats primarily municipal wastewater
  - Phases 2 and 3 treat a mixture of municipal and industrial wastewater
- MBR effluent will be used for industrial reuse applications

- Treatment Type: BOD, Nitrogen, Phosphorus Removal
- Membrane Area: 68,400 m² (36 HSM1800 modules)
- Net Flux: 28 LMH
- Commissioned: February 2012
Jurong WRP Retrofit

New MBR Footprint

Old CAS system
## Jurong – Feed/Filtrate Water Quality

<table>
<thead>
<tr>
<th></th>
<th>TSS</th>
<th>VSS</th>
<th>BOD</th>
<th>COD</th>
<th>NH3-N</th>
<th>TKN</th>
<th>PO4-P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mg/L</td>
<td>mg/L</td>
<td>mg/L</td>
<td>mg/L</td>
<td>mg/L</td>
<td>mg/L</td>
<td>mg/L</td>
</tr>
<tr>
<td>Annual Avg. – Primary Settling Tank OUT</td>
<td>120</td>
<td>101</td>
<td>179</td>
<td>452</td>
<td>35</td>
<td>42</td>
<td>7</td>
</tr>
<tr>
<td>Max Month – Primary Settling Tank OUT</td>
<td>149</td>
<td>125</td>
<td>229</td>
<td>530</td>
<td>43</td>
<td>52</td>
<td>10</td>
</tr>
<tr>
<td>Peak Day – Primary Settling Tank OUT</td>
<td>427</td>
<td>361</td>
<td>545</td>
<td>1287</td>
<td>65</td>
<td>79</td>
<td>28</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TURBIDITY</th>
<th>NTU</th>
<th>&lt; 0.2 for 95% of the time &lt; 0.5 for 100% of the time</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD</td>
<td>mg/L</td>
<td>&lt; 3.0 monthly average</td>
</tr>
<tr>
<td>COD</td>
<td>mg/L</td>
<td>-</td>
</tr>
<tr>
<td>NH3-N</td>
<td>mgN/L</td>
<td>&lt; 2.0 mg/L monthly average</td>
</tr>
<tr>
<td>TKN</td>
<td>mgN/L</td>
<td>-</td>
</tr>
<tr>
<td>NO3-N</td>
<td>mgN/L</td>
<td>&lt; 20 mg/L monthly average</td>
</tr>
<tr>
<td>PO4-P</td>
<td>mgP/L</td>
<td>&lt; 4.0 mg/L monthly average</td>
</tr>
<tr>
<td>Total coliform</td>
<td>CFU/100 mL</td>
<td>&lt;100 monthly geometric average</td>
</tr>
</tbody>
</table>
Membranes performance

TMP and Flux

- January 9 - 3000 ppm chlorine RC on Train C
- March 1 - 1000 ppm chlorine & 2% citric RC on Train E
- March 18 - 1300 ppm chlorine & 2% citric RC on Train B
- April 28 - 1% chlorine & 2% citric RC Reset on Train A, B & C
- August 16 - 5000 ppm Hypo RC on Train D, E & F
- August 2 - 5000 ppm Hypo RC on Train A, B & C
- June 13 - 1% citric RC on Train A
- May 4 - 1% chlorine & 2% citric RC Reset on Train D, E & F
- Oct 14 - 1% citric acid RC on Train A
Stone Brewery MBR-RO, USA

Background

- Located in Escondido, California
- 8500 sq.ft restaurant and 1 acre beer garden with on site brewery
- One of the fastest growing breweries in America over the last 10 years
- Have one of largest rooftop solar panel arrays in California
- BOD and TSS limits enforced by City of Escondido required them to build a treatment plant on site
Stone Brewery - Process Wastewater

- Mash tuns
  - Sugar, starch
- Boilers
  - Sugar, protein
- Centrifuges
  - Sugar, protein
- Fermentation tanks
  - Yeast, alcohol
- Bottle & keg rinsing
- Floor wash down
- Other process and storage tanks

Typical Raw Feed Water Quality

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>COD</td>
<td>mg/L</td>
<td>7000-12000</td>
</tr>
<tr>
<td>sCOD</td>
<td>mg/L</td>
<td>3000-5100</td>
</tr>
<tr>
<td>TSS</td>
<td>mg/L</td>
<td>1500-7300</td>
</tr>
<tr>
<td>T-N</td>
<td>mg/L</td>
<td>200</td>
</tr>
<tr>
<td>pH</td>
<td>s.u.</td>
<td>5.4-6.4</td>
</tr>
<tr>
<td>Temperature</td>
<td>°F</td>
<td>85-90</td>
</tr>
</tbody>
</table>
Stone Brewery - DAF Issues

- Sized for 150 gpm (820 m3/d) at 5000 mg TSS/L, but only able to process 20 gpm (110 m3/d)

- Excess waste had to be hauled off site
  $8500/week

- Excessive foaming and overflows

- High polymer usage for DAF and screw press
  $10,000/month

- Sludge handling difficult due to high water content
  Screw press dewatered sludge to 1-5% solids
Stone Brewery - DAF Results

- Exceeded TSS and COD on numerous occasions
  - $\text{BOD}_5/\text{COD} \sim 0.45-0.65$
  - Limits at maximum water usage of 25,000gpd (95 m3/d)

**Effluent Averages**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>COD</td>
<td>mg/L</td>
<td>354.8</td>
</tr>
<tr>
<td>TOC</td>
<td>mg/L</td>
<td>86</td>
</tr>
<tr>
<td>TSS</td>
<td>mg/L</td>
<td>164</td>
</tr>
<tr>
<td>pH</td>
<td>s.u.</td>
<td>7.2</td>
</tr>
<tr>
<td>Temperature</td>
<td>°F</td>
<td>99.3</td>
</tr>
</tbody>
</table>
Stone Brewery - MBR System

- Two HYDRAsub®-MBR modules: 2 x HSM500 = 1000 m²
- Design: 60 gpm (330 m³/d) at 12,000 mg TSS/L
- PVDF, 0.4 μm (MF), submerged HF membranes
- Weekly maintenance cleans: 300-500 ppm NaOCl
- Quarterly recovery cleans: 3000-5000 ppm NaOCl

All process water able to be treated
Meet City requirements 100% of the time
- 99.4% better TSS removal
- More consistent COD & BOD removal
- No polymer needed

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>HYDRAsub®-MBR</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSS</td>
<td>mg/L</td>
<td>&lt;2</td>
</tr>
<tr>
<td>Turbidity</td>
<td>NTU</td>
<td>&lt;0.2</td>
</tr>
<tr>
<td>Total coliform</td>
<td>cfu/100 ml</td>
<td>&lt;5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
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CONCLUSIONS

✓ Consolidated membrane tecnologies can offer innovative solutions and new applications by combination and process innovation
✓ There is not a «good» or a «bad» membrane; there is a proper application with the adequate process pretreatment
✓ Margin to improvement for energy saving, robustness and fouling resistance
✓ Advanced and integrated competences for plant design (chemistry, filtration theory, process engineering and automation, mechanical, hydraulic & civil engineering, ...)
✓ Piloting is key for unknow and new applications

Membrane can be a pr€ciou$ tool for turning challenges into opportunities
Thank you