Kotlarnica is Provider of Solutions, Equipment, Components, Engineering, and Technologies for HVACR Applications.

Through its Sister Company Kotlarnica is specialized in:

- Industrial Refrigeration (Ammonia and CO2 plants).
- Commercial Refrigeration (smaller capacity plants with halocarbon refrigerants).
- HVAC Systems.
- Large Scale Ammonia Heat Pumps Design & Manufacturing
• **Purpose Of the Presentation:**
  ✓ Describes Conducted Engineering R&D Aimed to Optimize Utilization of ASHP in Cold Winter Climates

• **Steps:**
  ✓ Defining Cold Climate Regions in Europe and Globally
  ✓ Energy, HVAC / Heating Solutions Trends by 2060
  ✓ Optimizing HVAC System Solutions In Line with ASHRAE, REHVA and Local Design Criteria
  ✓ Unique KOTLARNICA Solution at European Market  ❂ Kraftwerk EVI Optimized ASHPs
Global Climate Zones

- 20% of the World in Polar Zones
European Cold Climate Regions Number of Cold Days

Cold Climate Regions China

• **Chinese Climate Facts:**
  - **Five Major Zones**
    - Severe Colds
    - Cold
    - Hot Summer and Warm Winter
    - Mild
    - Warm Summer and Warm Winter

• **Heating Load Range very Diverse**
  - 1.0 kWh/m² in Hong Kong
  - 124.3 kWh/m² in Harbin

• **Cooling Load Range very Diverse**
  - 2.7 kWh/m² in Kumming
  - 23.5 kWh/m² in Beijing
Cold & Freezing Days Variations: SERBIA

Source: Serbian Hydro Meteorological Society / Seasonal Bulletin (2016 / 2017)
Cold & Freezing Days: Serbia 2016 / 2017

- Cold Days with Temperatures Lower than 0 °C
  - 65 to 81 Days in Central Serbia
  - 76 to 88 Days in Mountain Regions

- Freezing Days with Temperatures Lower than – 10 °C
  - 7 to 22 Days in Cities
  - 14 to 38 Days in Mountains

Source: Serbian Hydro Meteorological Society / Seasonal Bulletin (2016 / 2017)
Energy and Utilities Global Trends
Decarbonisation of Power Generation

- RTS Reference Technology Scenario, Limit Emissions NDCs Paris Agreement
- 2DS – 2 °C Scenario, 50 % Chance Limiting Global Warming for 2 °C by 2100
- B2DS – Beyond 2°C Scenario, Net Zero Emissions by 2060, Limiting to 1.75 °C by 2100

Source: OECD: Energy Technologies Perspectives (2017)
US National Average Levelized Costs of Electricity for New Generation Entering Service in 2022*

Source: National Academies of Sciences, Engineering, and Medicine 2016, Appendix B.

* Assumes $15 per ton of carbon dioxide emitted and adjusts for intermittency, the potential need for transmission investments, and the cost of criteria air pollutants.
Energy Demand of the Building

- Coefficient of Performance COP and Seasonal Performance Factors SPF
  - Energy Demands Required for Compressors, Heat Pump System related Components
  - The Heating Supply Temperatures are Derived from a Linear Interpolation Between the Design Heating Temperature (55°C or 35°C) at 100% of the Design Heating Demand and 20°C at 0% Heating Demand
  - Final Energy Demand: Division Hourly Useful Energy by the COP Values

Leveled Cost of Heat LCOH

- Cost of Producing Unit of Energy by Using Specific Technology
  - LCOH Includes Next Costs: Capital Investment, Fuel, Operations and Maintenance (O&M), Financing, and an Assumed Utilization Rate of the Plant
  - Efficient Tool Measuring Competitiveness of Different technologies
  - Calculated as NPV of all Costs and Benefits of a Specific Renewable Technology Divided by the Lifetime Energy Output of that Technology and is Expressed in €/MWh
# RESULTS OF LCOH ANALYSIS IN SERBIA, RESIDENTIAL SECTOR

<table>
<thead>
<tr>
<th>Heating Options</th>
<th>LCOH w/out externalities* €/MWh</th>
<th>LCOH with externalities* €/MWh</th>
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<td><strong>New individual heating systems (samo oprema)</strong></td>
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<tr>
<td>Coal stove (coal/lignite)</td>
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<td>Heat pumps</td>
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<td>Biomass stove (wood pellets)</td>
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<td><strong>Energy efficiency measures in households (single house)</strong> (uvođenje mera energetske efikasnosti)</td>
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<td>Coal stove (coal/lignite)</td>
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<td>Heat pumps</td>
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<td>54.31</td>
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*Externalities: Carbon Costs
Heat Pumps Key Markets Findings

- For Nearly All Buildings, Excluding Buildings Situated in Extreme Climates Sweden e.g. WSHP are Economically and Ecologically The Best Examined Solution.

- Due to Limited Water Availability Geothermal and Air Based Solutions Targeted as High Potential One
  - Standard ASHPs with Limitation of Operation Envelope for Cold Climate Zones

- Geological Circumstances, Legislation and Space limitations are to be Considered

- Very Efficient Systems Have Chances at Markets with High Energy Prices and also High Energy Demands

- In Low Energy Prices Countries and Low Energy Demand Countries the Investment Costs are Crucial Factors

- The Necessary Heating System Sizes for SFH 5 – 10 kW

- Hybrid Systems with Gas Boiler and Heat Pump will Have Good Chance in Countries with Low Gas Price

- Hybrid Systems with PV and Heat Pump will Have Good Prospective in Southern Countries

- In SFH in North and Middle Europe all New Buildings are Expected to Have Mechanical Ventilation in Future
Evolution of Heating Equipment

Heating Equipment Trends in Buildings by 2060

Source: OECD Energy Technology Perspectives (2017)
ASHPs Challenges
• Low Ambient Temperature Design Point
• Very High Cost of Maxigraph kW in Case of Electric Resistance Boiler Backup
• Number of Days Bellow – 10 °C
• Mechanical Designers Templates Set at – 12.1 °C Influencing ASHP Selection Procedures
• Investments Decision Making Criteria

Business Modeling Analysis

Bottom Up Modeling BEAM

Heat Pumps & HVAC Systems
Optimized for Future
• Main Ideas
  ✓ Implementing Systematic Optimization Techniques Provided Reliable Approach to Innovative Design and Advanced Heat Pump based HVAC System for Cold Climate
  ✓ Heat Pump Design was Optimized Using a Validated Component Based on Economized Vapor Injection (EVI) Model
  ✓ Extending the ASHP Envelope Maintaining High Level COP
  ✓ Maintaining the Product Cost at the Level Acceptable in Price Sensitive Regions and RES Markets
  ✓ Being Able to Respond to Low Regional Design Temperature Requirements
    ➢ ≈ -12 °C or Lower in Most of Targeted Markets

• Commercial Systems Energy Efficiency Solution
  ✓ Combining Kraftwerk Pumps with Patented Inductive Pulsation Diffusers

• Target
  ✓ Developing System Able Working Efficiently in Cold Climate Conditions
    ➢ Residential, Commercial, Industrial Solutions
  ✓ Eliminating Backup System Need
  ✓ Cold Climate HVAC Solution Running Cost Optimization
  ✓ Investment Value Optimization
• Standard ASHP Operation Limits Down to – 15 °C

- Vapor Refrigerant is Compressed in the Compressor
- Turns into High - Pressure and High – Temperature State and Flows Through The Condenser for Condensing
- Changing to Liquid after Dissipating Heat to Condenser
- Flow Through the Expansion Valve where Pressure and Temperature are Decreased Dramatically
- Continues as Two Stage Vapor Refrigerant through Evaporator Taking Heat From it
- Compressor Taking Vapor Refrigerant from the Evaporator (Closed Loop Vapor Evaporation Cycle)
- \( T_e < T_a \) to Collect the Heat, Reduced Density of the Refrigerant, Issues Low COP at Low Temperatures

- Possible Solution: Refrigerant Injection, Liquid and Vapor Refrigerant Injection
• **Economized Vapor Injection**

- **Liquid Refrigerant Injection** – Injecting Liquid – State Refrigerant into the Compressor
  - “Economizer Cycle” to Improve the Cooling / Heating Capacity at the Same Stroke Volume of the Compressor
- **Vapor Refrigerant Injection**
  - Decreasing the Extremely High Discharge Temperature of The Compressor
  - Ensuring The Reliable System Operation
**Solution Proposed and Executed**

- Economized (Enhanced) Vapor Injection Compressor (EVI) Utilization in ASHP VS Standard ASHP Design
- Best in Class Performance for Dedicated Heating Applications
- Technology Allows Replacement of Traditional Boilers both in New Buildings and Retrofit Buildings

Source: Copeland (2017)
• Operating Envelopes of Implemented Solutions
  ✓ EVI Fixed Speed Compressors Benefits

Source: Copeland (2017)
FEATURES & BENEFITS

✓ EVI Scroll Axial and Radial Compliance for High Reliability
✓ High Efficiency and Increased Heating Capacity
✓ High Water Temperature for all Applications
✓ Low Sound and Low Vibration Level
✓ Tandem Combination for Superior Seasonal Efficiency
✓ Enhanced Vapor Injection Technology for Best Seasonal Efficiency
• Operating Envelopes of Implemented Solutions
  ✓ Kraftwerk K Model ASHP Operating Envelope Established
  ✓ Combining with EVI Technology Unit Features Very Wide Temperature Range
  ✓ Reaches High Outlet Water Temperatures 55 to 60 °C Even at – 20 °C
  ✓ Works Safely and Reliably at Ambient Temperature of – 30 °C with Wet Injection Technology Applied
  ✓ Kraftwerk ASHP ability of working efficiently in cold climate has been confirmed
  ✓ It uses approx. 60% Less Energy than Electric Resistance Heating and its Ability while still Producing High Level COP > 2 Working Below – 20°C
  ✓ ASHP Setup Based on High Technical Skills and High Quality Operations and Processes of Manufacturing Partner in China, High Energy Efficiency and A ++ Energy Level are Presented under European ErP Directive
### KRAFTWERK K 16 A Model ASHP Characteristics Tested

#### KRAFTWERK K16 Heating Capacity & COP

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KOTLARNICA d.o.o. www.kotlarnica.rs, kontakt Petar Petrović, petar.petrovic@kotlarnica.rs, +38163362639
• Project Executed in IKEA Serbia
• Project Executed in IKEA Serbia

✓ Perforated Ducts with Patented Technology Creating Pressure Area on Their Axes Setting Controlled Motion of Total Air Mass

➤ Homogeneity of Both Horizontal and Vertical Temperatures (± 1°C regardless the Height of the Building)

➤ Maximum Comfort with Optimal Control of Residual Speeds in the Occupied Zone (0.2 m/s at 1.8 m Height)

➤ Total Destratification Especially for High Buildings even Higher than 40 m, ± 1°C Guaranteed

➤ Without Return Air Ducts, Reduced Pressure Loss for Fans, Less Maintenance, Less Ducts

➤ Total Recovery of all Endogenous Heat Produced in Treated Areas (Engines, Lightning, Etc…)

➤ Full Utilization of Dissipative Energy Mixing it With the Complete Air

➤ Possibility to Introduce Air at Low Temperature Directly in to the Room without Discomfort or Condensation Problems

➤ 30 Times Higher air Circulation Due to Turbulent Flow, Reduction of AHU Side Needs

➤ Heating Rooms with Low Temperatures Saving appx 30 % on number of kWh Covering Heat Losses still Achieving Desired Temperatures

➤ Reducing Speed of AHU units

➤ Extreme Winter Free Cooling Possibility, Allows Introducing Very Cold Air in to the Room, Down to – 15 °C Without Risk of Condensation or Lost Comfort

Pulsation Diffusion Systems
Diffusion Systems Performances Comparisons

![Graph showing performance comparisons of MIX-IND Pulsers, SPIROJET Diffusors, Nozzles, Variable Geometry, and Air Vents and Diffusers in terms of horizontal AIR THROW (m).]
Pulsation Diffusion Systems

Pulsation Diffusion Systems – Case Airbus
• **Project Made in Airbus Factory in France**

• **Description:**
  • Plant Surface: 7,000 m²
  • Medium Height: 14,5 m
  • Volumen: 100,000 m³
  • Filtration Class: ISO 8

• **Original Project Demand:**
  • Standard Diffusion System with Air Return Ducts:
    • Air Flow: 340,000 m³/h
    • Air Changes: 3,4 vol/h
    • Max Stratification: 2 °C
    • Return Ducts: ✔

• **Performed with Pulser:**
  • System with Pulsation Channels:
    • Air Flow: 150,000 m³/h
    • Air Changes: 1,5 vol/h
    • Max Stratification: 0,8 °C
    • Odvodni kanali: NO
AIRBUS EXECUTION: 1. Standard Diffusion Laminar, 2. Pulser Turbulent
Kraftwerk K Model Designed in the Way Achieving all Preset Targets

- Methods for Increasing the Performance of an Air Sourced Heat Pump (ASHP) Proven as Proper and Reliable
  - Economized Vapor Injection (EVI) Compressor Utilized in an Kraftwerk ASHPs Efficiently Runs in Cold Climate
- Advantages of Using System Heat Pump & Pulser Diffusion System for HVAC in Commercial and Industrial Projects (Advantages Referenced by Case Projects AIRBUS and IKEA) are Giving High Development Potential and Saving Area

Result:

- Extended ASHPs Operating Range that Eliminates the Need for a Backup Heating System in Cold Climate Regions
  - Reduction of Installed Electric Power (Multiple Benefits, Industrial, Commercial and Residential Wise)
  - Developed EVI ASHP Systems Able Working Efficiently in Cold Climate Conditions Down to – 30 °C Keeping High Efficiency
- Cold Climate HVAC Solution Running Cost Optimization
  - In Line with Described Influencers Backup System Elimination Providing Significantly Lower Running Costs
    - Even the Highest Heating Consumption Needs During Freezing Temperature Periods Covered by ASHP
    - Eliminating High Maxigraph Power Consumption Present in Case of Electric Resistance Boilers as Backup
    - High Level of Process Automation Possibility Eliminating Any Kind of Work Load: Main Operation and / or Backup
- Investment Value Optimization
  - Supply Chain Competitive Strategy Based on Chinese High Quality and Referenced Manufacturing Partner Securing Price Competitive Position for Kraftwerk ASHP Models in the European Cold Climate Markets
• Development Plans
  ✓ Two Stage Flash Separation Cycle Diagram
  ✓ Two Expansion Valves Utilization
    ➢ Second Expansion Valve to Directly Control the Interstage Injection Mass Flow Rate
  ✓ Keeping Additional Heat exchanger, Economizer, to Increase the Sub – Cooling of the Main Refrigerant Flow and to Increase the Vapor Mass Fraction of the Injection Stream
  ✓ Target Going Below – 40 °C Keeping COP at 1.5 at This Temperature Area

Do it Green Cool the Costs Down

www.kotlarnica.rs

Petar Petrovic: petar.petrovic@kotlarnica.rs

+38163362639