Name of the technology: 1.3 Tri-generation

Stage of development:
More than 500 systems with GE Jenbacher gas engines in combination with absorption chillers have been delivered worldwide.

Technical application:
Absorption chillers can be used to deliver a tri-generation solution for a combined heat and power plant.

Short summary (up to 200 characters):
Tri-generation or combined heat, power and cooling (CHPC), is the process by which some of the heat produced by a cogeneration plant is used to generate chilled water for air conditioning or refrigeration. An absorption chiller is linked to the combined heat and power (CHP) to provide this functionality. The recovered heat can be used for heating during the winter and for cooling during the summer. This provides an efficient way of maximizing the running hours at high total plant efficiency, benefiting both the owner and the environment.

Justification – why was this technology selected (up to 500 characters).
As living standards improve, demands for better comfort tend to increase along with more awareness of environmental issues. Better comfort leads to more widespread use of air conditioning and awareness of environmental issues leads to more efficient use of the fuel. Wärtsilä has responded to this challenge by developing solutions for tri-generation which is generally understood to mean the simultaneous conversion of a fuel into three useful energy products: electricity, hot water or steam and chilled water

There are a number of benefits to tri-generation including:

- Onsite, high efficiency production of electricity and heat
- Reduced fuel and energy costs
- Lower electrical usage during peak summer demand
- Engine heat can be used to produce steam of hot water for onsite use
- Significant reductions in greenhouse gas emissions
- No harmful chemical pollutants since water is used as the refrigerant
- Beneficial for improving building's energy efficiency ratings

Characteristics (up to 500 characters):
Tri-generation systems supply energy in three forms:

1. Electricity
2. Heat
3. Chilled water

Absorption chillers provide an economical and environmental alternative to conventional refrigeration.
Combining efficiency, low emission power generation equipment with absorption chillers allows for maximum total fuel efficiency, elimination of harmful refrigerants and reduced overall air emissions. There are a number of different configurations of CHP units where refrigeration can be derived. These include:
Absorption Chillers: operation using hot water/steam, or direct heat via combustion.
Compression-type refrigeration machines: direct drive power, or electrical drive power.

Combining a CHP or cogeneration plant with an absorption refrigeration system allows utilization of seasonal excess heat for cooling. The hot water from the cooling circuit of the plant serves as drive energy for the absorption chiller. The hot exhaust gas from the gas engine can also be used as an energy source for steam generation, which can then be utilized as an energy source for a highly efficient, double-effect steam chiller. Up to 80% of the thermal output of the cogeneration plant is thereby converted to chilled water. In this way, the year round capacity utilization and the overall efficiency of the cogeneration plant can be increased significantly.

Key Figures

- Approximately 150 - 170 kW of cold output is required per 1,000m^2 of office space
- The term tonnes of refrigeration (TR) is generally used as the unit of cold energy 1 TR (metric) = 3.86 kWh, 1 TR (US) 3.52 kWh
- The term coefficient of performance (COP) is used for referring to the efficiency of an absorption chiller. For a hot water chiller, the COP lies between 0.6 – 0.8 and for a double-effect steam chiller between 1.2 – 1.3
- Cold water temperatures down to 4.5°C can be achieved with lithium bromide salt
- Temperatures down to -60°C can be achieved with ammonia

Impact on the economy (up to 1000 characters):

Absorption chillers provide an economical and environmental alternative to conventional refrigeration.

Absorption based refrigeration technology offers the most established and economic solution for reduced emission, air conditioning systems.

- Operated with heat, utilizing relatively inexpensive 'excess energy'
- Production of electricity that can be fed into the power grid or used to cover the plant's electricity requirements
- During cold seasons, the heat can be utilized to cover heat requirements
- Absorption chillers have no moving parts, there for there is no wear and maintenance costs are low.
- Absorption system has noiseless operation
- Low operating costs and lifecycle costs
- Using water as a refrigerant replaces the use of ozone damaging substances.

The systems adapt easily to a variety of buildings (commercial and residential, hospitals, industrial facilities) and are easier to install. The technology is mature and proven. Main impact is on climate change (cogeneration), but the instalment of such systems also brings many advantages in other areas, like job creation and bettering of life standard.

Global development (up to 1000 characters):

Across the world, there is a new emphasis on projects that combine climate protection and economical primary power generation. Absorption chillers technology represents an optimal solution for a year-round efficient source of cooling and heat, especially when used in conjunction with a gas engine cogeneration plant.

A Quadgeneration system (CHPC and CO_2 Recovery) are some of the most advanced gas engine driven power plants in the world and takes this process one step further with the addition of systems to purify carbon dioxide from the engine exhaust.

Quadgeneration encompasses the features of a tri-generation system, with combined electricity, heat and cooling but in addition includes the recovery of carbon dioxide from the exhaust gas. This carbon dioxide is scrubbed and can be used in industrial process, in the horticultural industry, in greenhouses or offers the potential for carbon sequestration.

Benefits

- Potential for low or zero carbon emissions
- Reduced operational costs versus separate purchase of electricity, heat, cooling and carbon dioxide.
- Uses all potential resources from gas utilization
- Has a wide range of potential applications

Milestones[1] *(List at least one milestone per year against which the progress towards the achievement of the local/regional 2020 targets can be measured)*

Given the scope of the roadmaps (municipally or regionally based) technological improvements that would require major research and development processes would tend to fall outside of the scope of these roadmaps. This does not necessarily mean that such technological improvements cannot be used as milestones, but that before any such technological improvements are stipulated in the milestones, the capacity of the municipal and/or regional stakeholders, and the capacity of the municipality/region to collaborate with external partners, should be carefully considered.

Milestones more likely to fall within the scope of this roadmap are those that are able to help measure desired changes in the deployment and/or wider usage of the previously identified key energy technologies or those that measure the effects of this changed deployment or usage (i.e. production of thermal energy (GWh); increase of thermal energy production (%); installed capacity (GW or m2); increase of installed capacity (%); CO2 reduction (t)).

Year	2015	2016	2017	2018	2019	2020
Milestones					**10 MWcold*) installed capacity**	

The group assumed a hypothetical amount of 10 MWcold of installed tri-generation until 2020. They assumed an installed capacity of 10 MWcold in year 2019.

***) Chilled water from absorption chillers combined with 2 reciprocating engines.**

Financial Gaps

(List financially related challenges that need to be addressed in order to increase the uptake/wider usage of this technology)

1. **Lack of predictability when launching the financial instruments at national level.**
2. **High bureaucratic public procurement procedures**
3. **Lack of cooperation between public authorities and private investors.**

Policy Gaps

(List important policy gaps that prevent the uptake/wider usage of the key technology)

1. **Lack of interest and active involvement on behalf of local authorities**
2. **Lack of awareness-targeting actions meant to increase knowledge on legislative provisions, financial and technical solutions**
3. **Lack of interest from projects developers for disseminating, sharing experience, know-how and best practice**
4. **Lack of institutional transparency and high bureaucratic public procurement procedures.**

Financial Instruments and Period of Implementation

(List all relevant financial instruments that can address the above financial gaps and will contribute to the uptake/wider usage of the key technology. Please add the start year and years of important developments for the financial instrument.)

1. **Support actions for public-private partnership (PPP)**
2. **Support schemes for legal entities (reinvestment of profit)**

Policies and Period of Implementation

(List all relevant policies that can address the above policy gaps and will contribute to the uptake/wider usage of the key technology. Please add the start year and years of important developments for the policy.)

1. **Rising the level of importance and involvement of the local authorities**
2. **Transposition of the new Public Procurement Directive as well as the ex-ante conditionality on Public Procurement for accessing EU Structural funds 2014÷2020**
3. **Increasing institutional capacity of existing Programs Implementation Units (for accessing ESIF 2014-2020) in order to assist from the early stages of the project and reduce project evaluation processes**

Stakeholders

(List all relevant stakeholders for the implementation of the policy and/or financial instrument above)

1. **Municipalities, administrations, ministries.**
2. **Building associations, corporations.**

Policy Recommendations

(*Relevant policies for this particular technology have already been identified above. This section aims to provide the steps needed for the practical implementation of the policies and financial instruments listed above.)*

1. **Identification of "Champions" that could be the motivated players in starting the public-private partnership (PPP).**
2. **Organise meetings to develop the public-private partnership (PPP).**
3. **Formally launch public-private partnership (PPP) and start procuring absorption chillers at preferential prices.**