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UNIFHY

Regional Self-assessment

GREEN

PP03 – Energy Agency Southern Sweden
Kalmar County/Sweden

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Final - version

Content

Aim of the document

This Regional Self-assessment (RSA) will identify the barriers and challenges that are hindering the development of value chains of low carbon gases (i.e biomethane and hydrogen etc) as well as the opportunities that the low carbon gases could bring in the energy transition in the partners regions.

It will also provide a current vision of the political, economic, sociocultural, technological, legal, environmental, and other factors that could condition the development of this low-carbon gases ecosystem in each region.

This detailed analysis will allow to address the policy improvements for the specific regional policy instrument in the development of the low-carbon gases ecosystem, through several key objectives such as:

- Map the regulatory framework affecting the development and implementation of low-carbon gases within the region's energy system, including legislation, incentives, and potential constraints.
- Analyze the existing energy infrastructure and identify public and private facilities where low-carbon gases can be integrated as part of the energy transition.
- Explore challenges (such as funding limitations, regulatory barriers, technological bottlenecks, and the need for cross-sectoral coordination) in the implementation of low-carbon gases-based energy solutions.
- Identify the potential for low-carbon gases within the region's energy system and propose feasible strategies aligned with the region's long-term energy and climate goals.

Project identification

Acronym:	UNIFHY
Title:	Unifying policies to support the uptake of green hydrogen to decarbonize Europe
Project ID:	01C0212
Project duration:	01.04.2024 – 30.06.2028
Core Phase:	From 01.04.2024 until 31.03.2027
Follow-up Phase:	From 01.04.2027 until 31.03.2028
Closure Phase:	From 01.04.2028 until 30.06.2028

Partners / associated policy authorities

Project partners

LP01 - Consortium Extremadura Energy Agency – AGENEX (Spain)
PP02 – Aalborg Municipality (Denmark)
PP03 – Energy Agency Southern Sweden (Sweden)
PP04 – Moravian-Silesian Region (Czech Republic)
PP05 – South-East Energy Agency (Ireland)
PP06 – Lubelskie Voivodeship (Poland)

Associated policy authorities

APA01 – Directorate General for Industry, Energy and Mines - Regional Government of Extremadura (Spain, LP01)
APA02 – Region Kalmar County (Sweden, PP03)
APA03 – Waterford City and County Council (Ireland, PP05)

Project summary

In the EU Member States and their regions, there are different paces on the way to achieve climate neutrality; some of them are setting more ambitious targets and dates to reach it, while others are lagging to meet the intermediate targets established. For those regions that are in a favourable position, it is important to continue advancing in the more complex aspects of the energy transition, such as the transition of the gas sector to the use of renewable and low-carbon gases.

Although the share of renewable energy is increasing rapidly at EU level, the carbon dioxide emissions worldwide are still increasing. This means that all countries must also increase their efforts to decarbonize the energy sector, and the main challenge is to reduce fossil fuels in the end-use sectors, particularly in industry and transport.

Additionally, there are other challenges that must be overcome to decarbonize the energy sector, such as security of energy supply, environmental sustainability, and socio-economic aspects. To ensure a secure and stable energy supply, it is not enough to deploy new renewable power (wind, solar) if it cannot be stored to be used when demanded.

The set of proposals included in the Fit for 55 package provides a coherent and balanced framework for reaching the EU's climate objectives and it specifically includes shifting from gas to renewable and low-carbon gases, including hydrogen, and proposing a review of the EU gas market design. And in 2020, the European Commission proposed a hydrogen strategy for a climate-neutral Europe, aiming to accelerate the development of clean hydrogen as a cornerstone for a climate-neutral energy system.

UNIFHY will analyse policies and provide insights for policymakers in 6 EU regions: Aalborg Municipality (DK) and the Southern Sweden region (SE) in the North; Moravian-Silesian Region (CZ) and Lubelskie Region (PL) in the East; the South-East region of Ireland (IE) in the West; and Extremadura (ES) in the South.

RSA Executive summary

Green energy gases play a key role in achieving Swedish and global goals of fossil-free and resilient energy supply. In Kalmar County, biogas and hydrogen have been highlighted as key solutions to reduce climate impact, strengthen energy security and create regional development. This report has been produced within the framework of the European project UNIFHY and aims to provide a cross-sectoral analysis of the conditions for these energy carriers in Kalmar County. This report is primarily produced using data from the Swedish assessment reports *Hydrogen in Kalmar County – Mapping and Potential,*[1] and *Green Energy Gases in Kalmar County.*[2] Full references can be found in the respective reports. These materials have been complemented with socio-economic and energy-context in the Kalmar County, to facilitate understanding for the international reader.

Key findings

Biogas – an established and circular energy carrier

Kalmar County has a strong tradition of biogas production, especially from manure and other residual streams. Biogas is mainly used as vehicle fuel and in industrial processes and contributes to the circular economy by converting waste into energy and biofertilizer. The region has an established infrastructure, and long experience of collaboration between agriculture, municipalities and energy companies.

PESTLE summary for biogas

- **Political:** Strong regional collaboration and long-term climate goals, but lack of a national strategy and EU rules that disfavour biogas in procurements.
- **Economic:** *Klimatklivet* (a Swedish government investment grant for climate-related initiatives) has enabled investments, but tax uncertainty and low willingness to pay in industry are hampering development.
- **Social**: Community acceptance and potential for job creation but concerns about safety and odour may lead to resistance.
- **Technical**: The technology for biogas production is well established, and at the same time innovative progress is being made in methanation; however, there is dependence on the capacity of the electricity grid and external suppliers.
- **Legal**: Municipal support in permit processes, but there are complex regulations and a heavy administrative burden.
- **Environmental**: High climate benefit from manure-based biogas, but some risk of methane leakage and local environmental impact in large-scale production.

Hydrogen – an emerging key technology

[1] Energikontor Syd (2023). *Vätgas i Kalmar län – Kartläggning och potential*
[2] Energikontor Syd (2025). *Gröna energigaser i Kalmar län - Analys av hinder, möjligheter och utvecklingsfaktorer för biogas och vätgas inom energiomställningen*

Hydrogen is at an earlier stage of development but has great potential in heavy transport, industry and energy storage. Kalmar County has good access to both renewable electricity and nuclear power, which enables the production of both green and pink hydrogen. Several pilot projects are underway, but development is hampered by high investment costs, lack of users, infrastructure and expertise, as well as unclear regulations.

PESTLE summary for hydrogen

- **Political:** Municipal climate goals and the EU Green Deal[3] provide long-term steering signals, but the lack of a national hydrogen network and technology-neutral procurement creates uncertainty.
- **Economic**: *Klimatklivet* (a Swedish government investment grant for climate-related initiatives) has enabled certain investments in pilot projects, demonstrating the potential for local energy self-sufficiency and surplus sales. At the same time, progress depends on continued financial support and clearer policy instruments. Uncertain market development and high initial costs make it difficult for new actors to establish themselves.
- **Social**: Creates new jobs and strengthens regional identity but concerns about security, and lack of communication can reduce acceptance.
- **Technical**: Scalable technology and the possibility of local production with fossil-free energy, but energy losses and storage technology are challenging.
- **Legal**: The permitting processes for hydrogen projects are complex and can involve significant administrative challenges, especially when establishing new infrastructure. Regulations are often unclear and may be interpreted differently depending on the municipality and type of activity, creating uncertainty for stakeholders. Uncertainty regarding procurement rules and the division of responsibilities between authorities complicates planning and investment. Energikontor Syd does not provide legal support but works to increase general knowledge about hydrogen and its potential.
- **Environmental**: Fossil-free hydrogen reduces emissions, but water consumption and location in sensitive areas require careful consideration.

Conclusion and recommendations

Kalmar County has already shown leadership in the biogas field and taken important initiatives in hydrogen. The combination of biogas' circular strengths and hydrogen's future potential gives the county an opportunity to contribute to both national climate goals and regional development. With appropriate efforts, Kalmar County can continue to be a role model for sustainable energy transition – in Sweden and Europe. To realise the potential of biogas and hydrogen, six priority measures are proposed:

1. **Strengthen the integration of biofertilizer into the cycle** – through technology support, logistics solutions and collaboration with the Swedish Board of Agriculture.
2. **Establish a regional collaboration platform or green energy gases** – Build on existing initiatives such as Biogas Sydost and develop a broader platform that also includes

[3] *The EU Green Deal is a legally binding roadmap on climate- and environment-related challenges that aims to make the EU climate-neutral by 2050, with at least a 55% reduction in emissions by 2030.*

hydrogen and other green energy carriers. The platform should bring together private actors, academia, and civil society around shared goals for regional development and fossil-free energy. By offering opportunities to contribute with their own resources, for example, to a joint investment fund or project support, stakeholders can strengthen their sustainability profile, showcase green investments in their reporting, and simultaneously contribute to the region's climate goals. Such a structure can generate both goodwill and tangible PR value, while also promoting innovation, local engagement, and long-term collaboration.

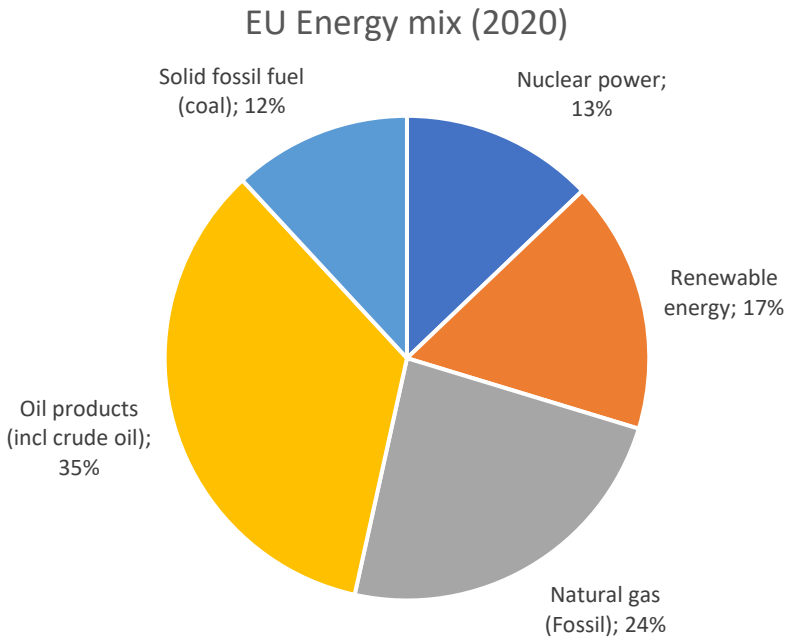
3. **Expand infrastructure for refuelling and storage** – especially in sparsely populated areas and along transport routes.
4. **Strengthen competence and support structures** – through a regional competence centre and improved visibility of existing support schemes.
5. **Simplify permit processes and increase legal certainty** – through regional guidelines and fast-track procedures.
6. **Increase social acceptance and communication** – through information efforts, early dialogue and good examples.

1. European context

(Maximum 2 pages) This section is written by PP03, with common information for each RSA

In 2020, 42% of the energy consumed within the EU[4] was also produced within the union, while nearly 60% was imported. Russia had long been the largest single supplier of energy to the EU. Some member states were more dependent on Russian energy than others, making them particularly vulnerable to energy shortages and rising energy prices.

The share of renewable energy in the EU's energy mix has steadily increased in recent years. Renewable energy accounted for approximately 22% of the EU's total energy supply in 2020. Regarding specific energy sources, oil products, including crude oil, made up about 35% of the energy mix, while natural gas accounted for 24%. Nuclear power contributed 13%, and solid fossil fuels, such as coal, represented 12% in the same year.



The European Union's transition to a climate-neutral economy necessitates a fundamental transformation of its energy system, with a particular emphasis on decarbonizing sectors that are difficult to electrify. Low-carbon gases, including green hydrogen, biomethane, and synthetic gases, are key enablers of this transition, supporting the EU's efforts to reduce reliance on fossil fuels, enhance energy security, and achieve a more integrated and resilient energy system. They serve as critical complements to renewable electricity from wind and solar, providing solutions for energy storage, industrial applications, and transport where direct electrification is impractical. Low-carbon gases are essential to achieving a secure, competitive, and sustainable European energy system. Through coordinated policy measures, infrastructure investments, and market incentives, EU is

[4] EEA

paving the way for a future where green energy gases play a central role in ensuring both climate neutrality and energy resilience.

At the core of this transformation is the EU Green Deal[5], which sets an ambitious target of achieving net-zero greenhouse gas emissions by 2050[6]. To meet this objective, the EU has developed a series of strategic frameworks aimed at scaling up the production, infrastructure, and market integration of green energy gases.

A pivotal policy in this context is the EU Hydrogen Strategy (2020)[7], which seeks to establish green hydrogen as a cornerstone of the European energy and industrial system[8]. The strategy outlines a phased approach, aiming to deploy 40 GW of electrolyser capacity by 2030 and foster the development of regional hydrogen clusters (hydrogen valleys) and cross-border infrastructure. This strategy is closely linked to broader European industrial policies, reinforcing hydrogen's role in decarbonizing hard-to-abate sectors such as steel production, chemicals, and heavy transport.

The geopolitical landscape has further underscored the urgency of energy diversification. The REPowerEU plan (2022)[9], introduced in response to the energy crisis and the need to reduce dependence on Russian fossil fuels, significantly accelerates the deployment of renewable gases. Under this plan, the EU aims to produce and import 20 million tons of renewable hydrogen annually by 2030 and expand biomethane production to 35 billion m^3/y, leveraging domestic resources and international partnerships. The current (year 2024) installed capacity[10] of biomethane production is 5,2 billion m^3 within EU.

Legislative frameworks such as the Fit for 55 package (2021)[11] reinforce these efforts by introducing carbon pricing mechanisms and sectoral targets that enhance the competitiveness of green energy gases. The updated Renewable Energy Directive (RED III, 2023)[12] further strengthens their role by setting a legally binding 42.5% renewable energy target by 2030, with additional support for biogas, green hydrogen, and Power-to-X technologies. Simultaneously, the TEN-E Regulation (2022)[13] provides the regulatory foundation for cross-border infrastructure development, ensuring the seamless integration of renewable gases into the European energy market.

Beyond policy and regulation, the EU is actively fostering industrial innovation through IPCEI (Important Projects of Common European Interest)[14]. This initiative channels funding into large-scale

[5] EU Green Deal
[6] 2050 long-term strategy
[7] EU Hydrogen Strategy (2020)
[8] A hydrogen policy framework
[9] REPowerEU (2022)
[10] Biomethane Europe
[11] Fit for 55 (2021)
[12] RED III (2023)
[13] TEN-E
[14] IPCEI

projects that support electrolyser manufacturing, hydrogen infrastructure, and advanced biogas applications, positioning Europe at the forefront of global low-carbon gas technologies.

The implementation of the European strategies and initiatives described above varies depending on each EU country's specific conditions and needs. By adapting these strategies to their national contexts, each EU country can contribute to achieving the EU's overarching goals of climate neutrality and energy security.

2. Regional Context

2.1. Basic socio-economic context

Indicator	Description
Territory	Kalmar County, located in southeastern Sweden
Surface area (km^2)	11,160 km^2
Total Population in your region	246,352 [15]
Number of municipalities in your region	12
Number of municipalities (<5,000 inhabitants)	0
Number of municipalities (>5,000 inhabitants)	12
Average number of inhabitants per municipality	20,529
Median net household income (€) [in your region and your country]	Kalmar: € 62,401 / Sweden: € 67,116 [16]
Household annual energy consumption in your Region (GWh)	Energy consumption: 2136 GWh, (2022)[17] of which: • Electricity consumption: 853 GWh • District heating: 594 GWh • Solid biofuels: 461 GWh • Other: 228 GWh
Industrial landscape	**Types of industries**: Manufacturing, agriculture, food processing, forestry, pulp and paper, bioenergy and e-health[18]. **Number and size of companies**: Total number of companies 13 976 [19]. The region is dominated by SMEs. Large companies are few but significant in employment and turnover. **Employment**: The overall unemployment figure In Kalmar County was 6,6 % in 2025, lower than the national average of 7,1 % for the same period.[20] Exact figures for industrial employment in Kalmar

[15] Population in the country, counties and municipalities on 31 December 2024 and Population Change in 2024
[16] Kalmar län. Based on an average household size of 2.2 persons. Exchange rate used: 1 SEK = 0.089 EUR (as of August 21, 2025).
[17] Slutanvändning (MWh) efter region, förbrukarkategori, bränsletyp och år. PxWeb
[18] Region Kalmar - SBHSS
[19] Antal företagsförekomster per kommun, 2021
[20] Kalmar - Tillväxtverket

County are not publicly available in recent sources. However, manufacturing and related sectors are known to employ a significant share of the regional workforce, particularly in machinery, food processing, and bioenergy.

Production and capacity: Kalmar County has internationally competitive strengths in food, forestry, tourism, and manufacturing. Its economy is driven by many small and medium-sized enterprises, with large industrial firms playing a key role in employment and value creation.
Despite having just over 2% of Sweden's population, Kalmar produces: 25% of the country's chicken; over 10% of its milk, eggs, and beef; and nearly 100% of Sweden's brown beans.[21]

Economic significance: The Gross Regional Product (GRP) of Kalmar County 2025 was 113 billion SEK, of which industrial goods was approximately 31 %.[22] This figure can be compared to the national average GRP of 293 billion SEK for the same period.

[21] Våra styrkor - Regional utveckling Kalmar län
[22] Kalmar - Tillväxtverket

2.2. Energy context

2.2.1. Regional energy production

Regional Energy production (sources)	**Description**
Energy mix (GWh)[23]	**2022:** Ambient heat 333 GWh (3 %) Electricity produced outside the county: 858 GWh (7%) Electricity (regional wind power): 1,485 GWh (12%) Electricity (regional solar power): 78 GWh (<1%) Electricity (regional hydropower): 44 GWh (<1%) Solid biofuels: 2,785 GWh (22%) Liquid biofuels and black liquor: 4,923 GWh (39%) Biogas: 61 GWh (<1%) Liquefied petroleum gas/natural gas: 72 GWh (<1%) Fossil oil products: 2,102 GWh (16%)
Electricity production (GWh) [24]	**2023:** Combined heat and power: * Nuclear: 9,165 GWh Water: * Wind: 1,542 GWh Solar: 131 GWh **Total: 11,874 GWh** **2022:** Combined heat and power: 915 GWh Nuclear: 10,401 GWh Water: 44 GWh Wind: 1,485 GWh Solar: 78 GWh **Total: 12,922 GWh** *Confidential
Biogas (GWh)	2023: 63 GWh[25] 2022: 63 GWh [26]
Hydrogen (GWh)	No commercial hydrogen production plants yet. The nuclear power plant in Oskarshamn however have produced hydrogen

[23] Energibalans för 2022, Kalmar län
[24] Statistikdatabasen SCB, Produktion Kalmar län 2022-2023
[25] biogasstatistikrapport_2023_slutversion-240930-sammanfogad.pdf
[26] biogasstatistikrapport_2022_webbs2.pdf

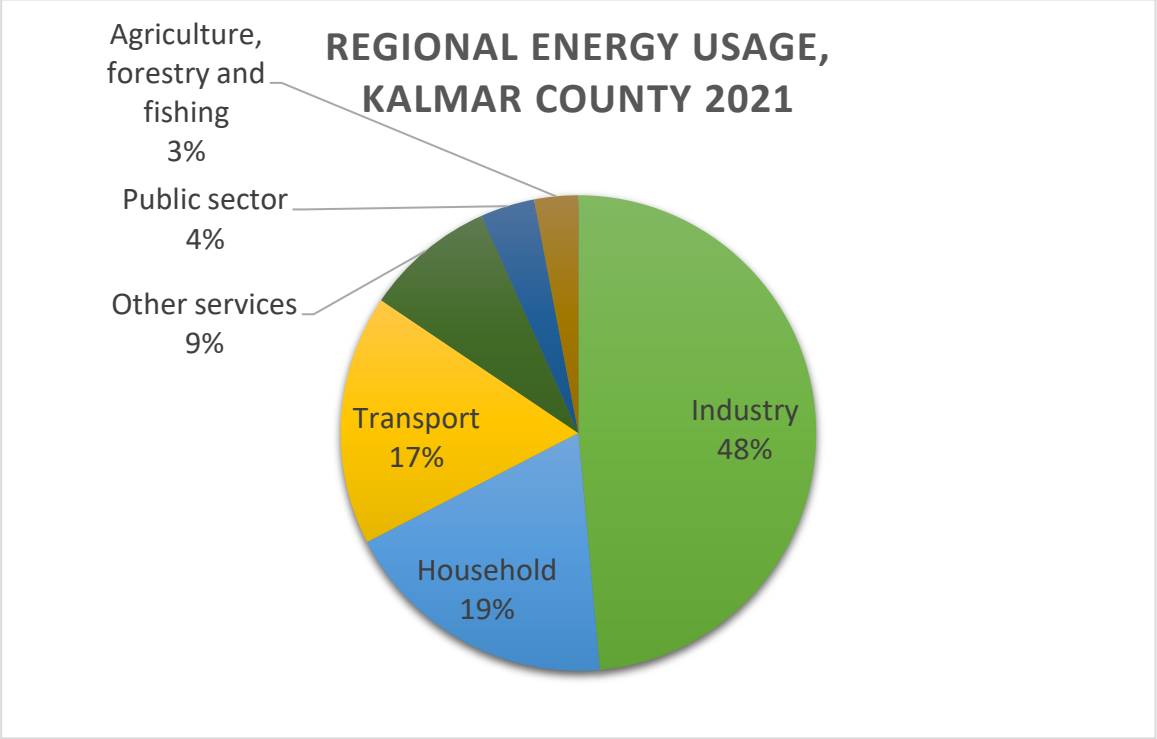
	for internal use since 1992 and sell some surplus to external parties. [27]
Total energy use in the region (GWh) [28]	**End use (2022)** Electric energy: 3,311 GWh District heating: 1,098 GWh Renewable energy (excl. Heat pumps): 4,837 GWh Heat pumps: 333 GWh Non-renewable energy: 1,975 GWh **Total: 11,600 GWh** **Biogas in the transport sector: 61 GWh**
Whereof produced on regional level %	Electric energy: 76 %** District heating: * Renewable energy (excl. heat pumps): * Heat pumps: * Non-renewable energy: * **Total: 38 %** **Biogas: >100 % (the region is a net exporter of energy)** ****Electric energy:** In the energy balance report for Kalmar County 2022, electricity produced at the nuclear power plant in Oskarshamn (more than 10 TWh) has been considered a national matter and is therefore not included in their report. According to that reasoning, the county is not self-sufficient in electricity. *Confidential

2.2.2. Regional energy usage

Energy use in Kalmar municipality is distributed across several sectors. In 2021, the largest share was industry, accounting for 5,569 GWh (48%) of total energy use. The household sector used 2,162 GWh (19%), and transport accounted for 1,952 GWh (17%). The total energy use for all sectors was 11,468 GWh.[29]

Note that for several sectors, recent statistics on energy consumption after 2021 are not available due to confidentiality in official reporting. As a result, data for 2022 and 2023 for sectors such as industry, transport, households, other services, and the public sector are withheld and cannot be presented in the table.

[27] Energikontor Syd (2023). *Vätgas i Kalmar län – Kartläggning och potential*
[28] Energibalans för 2022, Kalmar län
[29] Statistikdatabasen SCB, Slutanvändning Kalmar län 2021-2023


REGIONAL ENERGY USAGE, KALMAR COUNTY 2021
Agriculture, forestry and fishing 3%
Public sector 4%
Other services 9%
Transport 17%
Household 19%
Industry 48%

3. Policy and Regulatory framework

The development of biogas and hydrogen in Kalmar County is closely tied to the evolution of policies at the EU, national, regional, and local levels. Regulations, targets, and financial instruments shape both the opportunities and barriers for market development.

This section reviews the existing policy framework, its transposition to the regional level, and provides recommendations to improve regulatory conditions in line with the UNIFHY project's objectives.

European and National Policy Context

- **European Union**
  - European Green Deal and Fit for 55 packages: Binding targets for climate neutrality by 2050 and 55% emissions reduction by 2030.
  - Renewable Energy Directive (RED II/III): Mandates for renewable fuels of non-biological origin (RFNBOs), advanced biofuels, and biogas injection into grids.
  - EU Hydrogen Strategy (2020): Target of 40 GW electrolysis capacity by 2030.
  - Alternative Fuels Infrastructure Regulation (AFIR): Requires hydrogen refuelling stations every 200 km along TEN-T corridors by 2030.
  - Sustainable Finance Taxonomy: Defines sustainable investments, critical for financing biogas and hydrogen projects.
- **Sweden (National Level)**
  - National Hydrogen Strategy (2021): Targets 15 GW electrolysis capacity by 2045, prioritizing industrial decarbonization and transport. Still under development, with auctions and support mechanisms to be introduced.
  - Climate Policy Framework: Climate neutrality by 2045, with intermediate targets for emission reductions by 2030 and 2040.
  - Biogas Market Inquiry (Biogasmarknadsutredningen, 2019): Proposed long-term policy framework for biogas subsidies, aiming to strengthen competitiveness.
  - Support Programs:
    - *Klimatklivet* (investment support for biogas and hydrogen infrastructure, administered by the Swedish Environmental Protection Agency).
    - *Industriklivet* (decarbonization of industry, including hydrogen, administered by the Swedish Energy Agency).
    - *Electrification Pilots* (funding hydrogen refuelling stations and heavy-transport pilots, administered by the Swedish Energy Agency).
  - Transport policy: Zero-emission vehicle mandates and public procurement favouring renewable fuels.

Regional and Local Policy Context (Kalmar County)

- **Region Kalmar County**
  - Fossil-Free Region 2030: Official target to eliminate fossil fuel use by 2030.

  - Regional Energy and Climate Strategy: Promotes both biogas and hydrogen as complementary solutions.
  - Energikontor Syd (Regional Energy Agency): Supports municipalities and SMEs in project development and EU funding applications.
  - Role in UNIFHY Project: Kalmar acts as a pilot region for evaluating policies and developing innovation pathways for hydrogen and biogas.
- **Municipalities**
  - Kalmar Municipality: Host to a planned hydrogen refuelling station and supportive of biogas use in municipal fleets.
  - Oskarshamn Municipality: Location of OKG nuclear plant, producing surplus hydrogen; strategic in testing hydrogen for industry and transport.
  - Waste Management Policies: Municipalities ensure source-separated organic waste collection, supplying feedstock for biogas plants.

UNIFHY Focus Areas and Policy Relevance

- **Hydrogen Auctions**: Sweden is preparing mechanisms for competitive hydrogen auctions, in line with EU Hydrogen Bank principles. Kalmar County could position regional producers (nuclear + renewable) for participation.
- **Electrolysers**: Current projects in Kalmar Conty are small-scale, but national targets (15 GW) imply regional opportunities. Policies should enable co-location with nuclear and wind power.
- **Biogas Implementation**: Kalmar County already demonstrates circular biogas use in transport and agriculture. National subsidies (Klimatklivet, biogas support schemes) are critical for continued competitiveness.
- **Infrastructure Development**: In the municipalities of Kalmar and Oskarshamn, hydrogen refuelling stations are co-funded by national programs. Expansion will depend on AFIR (Alternative Fuels Infrastructure Regulation) compliance and regional planning.
- **Cross-Sector Integration**: Policies encourage synergies (e.g., electrolysis heat to district heating, digestate to agriculture), but no comprehensive framework exists to mandate or incentivize integration.

Regulatory Barriers and Policy Gaps

- **Permitting complexity**: Biogas projects face long approval times; hydrogen lacks clear regulatory categories (storage, safety, distribution).
- **Policy uncertainty**: Biogas tax exemptions and subsidies are short-term, deterring long-term investments.
- **EU procurement rules**: Current frameworks may disfavour biogas compared to electricity or hydrogen, limiting municipal uptake.
- **Infrastructure gap**: AFIR targets not yet fully integrated into regional planning; refuelling networks remain underdeveloped.
- **Market immaturity**: Hydrogen demand is still nascent; few instruments exist to guarantee industrial offtake.
- **Knowledge gaps**: Municipal and SME actors lack clear guidance on available funding streams and technical standards.

Recommendations for Adequate Policy Framework

- **Policy and Regulation**
  - Stabilize support schemes: Provide long-term certainty on biogas tax exemptions and hydrogen subsidies.
  - Streamline permitting: Introduce regional fast-track approval processes for biogas and hydrogen projects.
  - Harmonize safety and technical standards for hydrogen infrastructure at national and regional levels.
- **Financing and Market Creation**
  - Expand the investment grants *Klimatklivet* and *Industriklivet* allocations to biogas and hydrogen infrastructure in agricultural and industrial contexts.
  - Facilitate blended financing by enabling municipalities and regional companies to issue green bonds for infrastructure.
- **Infrastructure and Integration**
  - Align AFIR targets with regional planning, ensuring hydrogen refuelling stations and biogas distribution to cover freight corridors.
  - Promote sector coupling policies — integrate hydrogen electrolysis into district heating and biogas digestate into agricultural policy.
- **Governance and Capacity Building**
  - Strengthen and expand the existing regional low-carbon gas platform to include hydrogen and other renewable gases, enabling coordinated projects, knowledge sharing, and more effective policy advocacy.
  - Enhance citizen and SME engagement through participatory financing (cooperatives, green shares) and targeted information campaigns.

4. PESTLE Analysis

This chapter provides a structured assessment of the internal and external factors influencing the implementation of a low-carbon ecosystem in Kalmar County, with a focus on two key energy carriers: **biogas** and **hydrogen**. The chapter is divided into two main sections, each dedicated to one of the key energy carriers.

PESTLE Analysis Biogas in Kalmar County

Biogas plays a central role in Kalmar County's transition to a sustainable and circular energy system. With strong local roots in agriculture, established technology and political support, biogas has developed into an important energy carrier for both transport and industry. At the same time, the sector faces challenges related to regulations, market conditions and social acceptance. The table below summarizes the main strengths, opportunities, risks and challenges of biogas, structured according to the PESTLE model and linked to the entire value chain.

Kalmar County has strong potential for biogas development thanks to robust regional leadership, long-term political continuity, and broad collaboration between municipalities, industry, and academia. The investment grant *Klimatklivet* has enabled substantial investments in production, upgrading, and infrastructure, while local feedstock availability enhances energy security and creates new revenue streams for agriculture.

The greatest opportunities lie in the climate benefits of biogas, particularly from manure-based production which results in negative emissions, and in technological innovation such as methanation and liquefaction to LBG. Biogas also contributes to rural development and the circular economy, with strong local roots and social acceptance. Export opportunities for both gas and technology further strengthen the region's role in the green transition.

At the same time, there are significant challenges. Lack of national coordination, uncertain tax policies and EU Regulations that disadvantage biogas create investment uncertainty. Public procurement tends to favour cheaper alternatives such as HVO100, threatening existing infrastructure. Substrate competition, technical permitting issues and negative public opinion to new facilities make expansion difficult, especially for smaller players.

Nevertheless, the future of biogas in Kalmar County looks promising, provided that political and legal obstacles are addressed. With continued support from *Klimatklivet*, technological advancement, and increased awareness of biogas's climate benefits, the county can solidify its position as a biogas frontrunner. A clear national strategy and fair procurement conditions are crucial to securing long-term growth and realizing the full potential of biogas in the region's energy transition.

Factor	Strengths / Opportunities	Weaknesses / Threats
Political	- Kalmar County has strong regional leadership and long-term political continuity. - Biogas is integrated into climate strategies and public transport. - Regional collaboration (e.g., Climate Cooperation Kalmar County) enables joint investments.	- Lack of a national strategy creates uncertainty across the entire value chain. - EU's focus on so-called tailpipe emissions puts biogas at a disadvantage in public procurement. - Biogas is excluded from new public transport procurements despite existing infrastructure.
Economic	- The funding programme *Klimatklivet* has co-financed 80% of production. - Local production from manure reduces import dependency and strengthens energy security. - Export opportunities for LBG (Liquefied Biogas) and technology (e.g., Wärtsilä Puregas).	- Tax uncertainty has hampered investments. - Competition for substrates leads to price escalation and puts small actors at a disadvantage. - Low willingness to pay within industry and difficulties in accessing EU funding.
Sociocultural	- Strong local engagement among farmers and cooperative operations. - Job creation in rural areas. - Projects like *Biogasboost* have increased awareness and public acceptance.	- Negative public opinion following incidents involving gas-powered vehicles (e.g., buses). - Concerns about odour, explosions, and traffic have halted projects. - Insufficient communication and low awareness among decision-makers.
Technological	- Mature and flexible technology adapted to local substrates. - Innovation in methanation and upgrading to LBG. - New gas-powered heavy-duty vehicles (e.g., Scania 460 hp, 1800 km range).	- Permitting issues due to public and local resident pressure. - Delays in pilot projects caused by supplier bankruptcies. - Technical limitations in transport and storage, with costly and inefficient nutrient separation. - With potential expansion of hydrogen there is an ack of refuelling stations, storage solutions, and electrical grid capacity to support local production.
Legal	- Municipal support in permitting processes has shortened lead times. - The EU's RED III and Green Deal favour biogas from residual products. - Potential inclusion in Sweden's fuel emission reduction scheme from 2025	- Environmental permitting is complex and unpredictable. - EU classification limits support for crop-based biogas. - High administrative burden for small actors seeking EU funding.
Environmental	- Manure-based biogas delivers negative emissions and reduces agriculture's climate impact. - Reduces eutrophication and improves soil quality. - Strengthens the circular economy and energy resilience.	- Long transport distances to large-scale facilities reduce climate benefits. - Odour, methane leakage, and noise from large facilities. - Land-use conflicts and local opposition to infrastructure development.

Kalmar County has strong potential for biogas development thanks to robust regional leadership, long-term political continuity, and broad collaboration between municipalities, industry, and academia. The investment grant *Klimatklivet* has enabled substantial investments in production, upgrading, and infrastructure, while local feedstock availability enhances energy security and creates new revenue streams for agriculture.

The greatest opportunities lie in the climate benefits of biogas, particularly from manure-based production which results in negative emissions, and in technological innovation such as methanation and liquefaction to LBG. Biogas also contributes to rural development and the circular economy, with strong local roots and social acceptance. Export opportunities for both gas and technology further strengthen the region's role in the green transition.

At the same time, there are significant challenges. Lack of national coordination, uncertain tax policies and EU Regulations that disadvantage biogas create investment uncertainty. Public procurement tends to favour cheaper alternatives such as HVO100, threatening existing infrastructure. Substrate competition, technical permitting issues and negative public opinion to new facilities make expansion difficult, especially for smaller players.

Nevertheless, the future of biogas in Kalmar County looks promising, provided that political and legal obstacles are addressed. With continued support from *Klimatklivet*, technological advancement, and increased awareness of biogas's climate benefits, the county can solidify its position as a biogas frontrunner. A clear national strategy and fair procurement conditions are crucial to securing long-term growth and realizing the full potential of biogas in the region's energy transition.

PESTLE Analysis hydrogen in Kalmar County

Hydrogen is increasingly highlighted as a key technology in the energy transition, particularly for sectors where electrification is challenging. In Kalmar County, several initiatives are underway to establish local production of green hydrogen, often through collaboration between municipalities and industry. The potential is significant – but so is the complexity. Investment, infrastructure, safety and social acceptance are all critical factors. The SWOT-table below provides an overview of hydrogen's strategic position in the region, with a focus on political, economic, social, technological, legal and environmental aspects.

Kalmar County is beginning to establish itself as a forward-looking region for hydrogen, with several municipalities driving projects focused on fossil-free hydrogen production. The region has a relatively strong starting position thanks to local fossil-free electricity generation and growing interest from both municipal actors and industry.

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Factor	Strengths / Opportunities	Weaknesses / Threats
Political	- Municipal climate goals and fossil fuel phase-out ambitions by 2030. - The EU's Green Deal and national hydrogen strategy provide long-term policy signals. - Regional collaboration through Energikontor Syd strengthens project development. - Competitive advantage from lower electricity prices in SE3[30] supports hydrogen production and incentivizes local energy investments.	- Slow decision-making processes and unclear policy instruments at the national level. - Technology-neutral procurement favours cheaper alternatives such as HVO100. - Absence of a national hydrogen grid hampers large-scale distribution. - Higher electricity prices in SE4 compared to SE3 reduce profitability and risk uneven regional development.
Economic	- Potential for local energy self-sufficiency and long-term cost neutrality. - Surplus production can be sold to other actors (e.g., Gotland ferry operations). - Regional collaboration reduces unit costs and increases system redundancy.	- High initial investment costs for electrolysers, storage, and infrastructure. - Project profitability depends on complex EU and national support schemes. - Uncertain market development for electricity and hydrogen prices complicates business models.
Sociocultural	- Creates new jobs in technology, operations, and logistics. - Strengthens local identity as a sustainable energy region. - Can be used for energy preparedness in critical infrastructure.	- Safety concerns (risk of explosion, high pressure) may lead to public opposition. - Lack of communication and stakeholder engagement reduces legitimacy. - Geographic differences in needs and acceptance between urban and rural areas.
Technological	- Green hydrogen can be produced locally using fossil-free energy without burdening the electricity grid. - The technology is scalable and allows for gradual expansion. - By-products (oxygen, heat) can be utilized in other systems.	- Storage technologies are costly and technically demanding (high-pressure, cryogenic storage). - The efficiency of electrolysis and other conversion processes varies depending on technology and application. If this waste heat cannot be utilized, energy losses are significant. - Lack of local expertise and dependence on external suppliers. - Vehicle technology for heavy-duty transport is immature and limited in availability.
Legal	- The funding programme *Klimatklivet* can serve as a gateway to larger EU funding opportunities.	- Complex permitting processes and safety requirements delay projects. - Difficult to prioritise local suppliers in public procurement.

[30] *SE3 and SE4 refer to electricity price zones in Sweden, where SE3 covers central regions including Stockholm and Gothenburg, and SE4 encompasses southern Sweden, often characterized by higher electricity prices due to limited production and transmission capacity.*

	- RED III and the EU's industrial policy open possibilities for future support mechanisms.	- Risk of appeals in procurement and investment processes.
Environmental	- Fossil-free hydrogen reduces emissions from heavy transport and industry. - Production using fossil-free electricity lowers climate impact. - Oxygen as a by-product can be used to counteract hypoxia in the Baltic Sea.	- Environmental permits may be required depending on technology and site location. - Water consumption may lead to resource conflicts in agricultural areas and water-intensive industries. - Waste heat is difficult to utilize without adapted infrastructure.

Kalmar County is beginning to establish itself as a forward-looking region for hydrogen, with several municipalities driving projects focused on fossil-free hydrogen production. The region has a relatively strong starting position thanks to local fossil-free electricity generation and growing interest from both municipal actors and industry.

For Kalmar County, the greatest opportunities lie in local production of green hydrogen via solar energy, use in heavy transport and industry, as well as integration with existing systems – such as wastewater treatment plants and district heating. Hydrogen can also contribute to crisis preparedness and energy security, particularly in sparsely populated municipalities. The technology's scalability and potential to create new jobs make it attractive for regional development.

The main challenges include high investment costs, complex permitting processes, and a lack of national coordination, all of which complicate implementation. Hydrogen's technological immaturity – especially in storage and vehicles – along with public concerns about safety, also pose barriers. Additionally, access to water is a critical factor, particularly in a county that experiences recurring droughts.

The future of hydrogen in Kalmar County is promising but depends on clear policy instruments, collaboration, and continued technological development. If the region succeeds in overcoming legal and technical hurdles, hydrogen could become an important complement to biogas and electricity in the county's energy transition—especially in sectors that are difficult to electrify.

5. Key players, stakeholders and value chain

The transition to a fossil-free energy system in Kalmar County relies heavily on low-carbon gases, primarily biogas and hydrogen. Both energy carriers are at different maturity levels: biogas is well established, while hydrogen is emerging. Together, they form complementary pillars in the regional low-carbon gas ecosystem. The effectiveness of this ecosystem depends on a wide range of stakeholders across the value chain – from feedstock providers and producers to distributors, end-users, and supporting institutions.

This section outlines the key players, their roles, and the mechanisms through which they contribute to the development of low-carbon gases in Kalmar County. It also highlights how public authorities engage with private actors and citizens to accelerate adoption.

The Value Chain for Low-Carbon Gases

The value chain for biogas and hydrogen in Kalmar County consists of five interlinked stages:

1. **Feedstock and Input Supply**
    - Biogas: Agricultural residues (livestock manure, crop residues), food industry by-products, municipal organic waste, and sewage sludge.
    - Hydrogen: Renewable electricity (solar, wind), nuclear power (Oskarshamn), and water resources for electrolysis.
2. **Production**
    - Biogas production through anaerobic digestion at farm-based plants, municipal treatment facilities, and industrial-scale biogas plants.
    - Hydrogen production via electrolysis, currently on a pilot scale, but with potential for both *green hydrogen* (renewable electricity) and *pink hydrogen* (nuclear-based).
3. **Processing and Upgrading**
    - Biogas upgrading to biomethane for injection into the grid or liquefaction (LBG).
    - Hydrogen purification, compression, or liquefaction for mobility and industrial uses.
4. **Distribution and Infrastructure**
    - Gas grids, local pipelines, and refuelling stations.
    - Emerging hydrogen refuelling stations in Kalmar municipality and Oskarshamn municipality (supported by *Klimatklivet* and *Electrification Pilots*).
5. **End-Use and Applications**
    - Biogas: Public transport (Kalmar Länstrafik), heavy-duty vehicles, local industries (food, metal, drying processes), electricity and heat generation, and fertilizer through biogas digestate.
    - Hydrogen: Pilot use in municipal vehicle fleets, potential for heavy transport, energy-intensive industry (glass, food, foundries), backup power, and integration with district heating systems.

Key Players and Stakeholders

- **Public Authorities and Regional Governance** provide strategic frameworks, co-finance infrastructure, simplify permitting, and promote collaboration platforms.
    - Region Kalmar County: Coordinates the regional energy and climate strategy, with the target of becoming a fossil fuel free region by 2030. Provides political leadership and funding support.
    - Municipalities: Critical in waste collection (substrates for biogas), permitting processes, and procurement policies favouring renewable fuels. Examples: Kalmar municipality (hydrogen refuelling), Oskarshamn municipality (industrial hydrogen and nuclear synergies).
    - Energikontor Syd: Facilitates regional energy projects, conducts studies, and acts as a bridge between public sector, private companies, and civil society. Key initiator of biogas and hydrogen projects.
    - Swedish Agencies: The Swedish Energy Agency (funding via electrification pilots) and Swedish Environmental Protection Agency (Klimatklivet investment program).

- **Private Sector – Producers and Technology Providers** drive technological implementation, invest in infrastructure, and bring products to market.
    - Biogas Producers: Local farms, cooperatives, municipal wastewater plants, and companies such as Gasum (though with paused projects in Kalmar County).
    - Hydrogen Producers:
        - OKG Nuclear Plant (Oskarshamn) – producing hydrogen since 1992 for internal cooling, now selling surplus externally.
        - Hydri (formerly ReH2) – developing hydrogen refuelling stations, with 24 planned nationally, including one in Kalmar municipality.
        - PS Energi – building a hydrogen station in Oskarshamn municipality.
    - Technology Suppliers: Electrolyser manufacturers, upgrading and storage technology providers (mostly external to Kalmar County but critical for scaling production).

- **End-Users – Transport, Industry, and Agriculture** create demand for low-carbon gases and close the circular loop through feedstock supply.
    - Transport sector:
        - Kalmar Länstrafik (KLT): The regional public transport authority of Kalmar County. Pioneer in using biogas buses, a long-standing anchor for demand.
        - Logistics companies and hauliers: Potential early adopters of hydrogen for heavy-duty vehicles.
    - Industry: Food industry (e.g., Åbro Bryggeri), glassworks, and foundries – possible hydrogen users for high-temperature processes.
    - Agriculture: Supplies feedstock for biogas, uses biogas digestate as fertilizer, and could adopt hydrogen or biomethane in farm machinery.

- **Knowledge, Research and Civil Society** enhance innovation, acceptance, and diffusion of technology.

- Universities and research institutions: Provide expertise on process optimization, system studies, and innovation in gas technologies.
- Industry associations (e.g., LRF – Federation of Swedish Farmers): Promote farmer engagement in biogas.
- Citizens and consumers: Both as waste suppliers (household organic waste for biogas) and as consumers of clean mobility and sustainable food systems.

Involvement of Stakeholders and Cooperation Models

- **Public–Private Partnerships (PPP)**: Essential for infrastructure development (e.g., hydrogen refuelling stations co-financed by *Klimatklivet* and private operators).
- **Regional Clusters**: Creating a regional platform for green gases, uniting SMEs, farmers, municipalities, energy companies, and universities to coordinate investments and innovation.
- **Citizen Engagement**: Information campaigns and participatory planning help build trust, address concerns (odour from biogas, safety of hydrogen), and promote social acceptance.
- **Procurement and Market Creation**: Municipal procurement of biogas buses and public vehicles serves as a market signal to drive private investments.

Contribution to a Thriving Ecosystem

By mobilizing actors across the value chain, Kalmar County can position itself as a regional leader in low-carbon gases.

- **Public Authorities**: Shape enabling policies, streamline permits, and co-finance infrastructure.
- **Private Companies**: Innovate, invest, and operate production and distribution systems.
- **Industries and Farmers**: Anchor demand, supply critical inputs, and create business cases for expansion.
- **Citizens and Civil Society**: Contribute to resource flows, adopt clean energy solutions, and strengthen social legitimacy.

6. Low-carbon gases as a solution for the energy transition

The transition to a fossil-free society is a cornerstone of Kalmar County's regional climate and energy strategy, which aims for a fossil fuel free region by 2030. Achieving this target requires particular attention to hard-to-electrify sectors where direct electrification is technically, economically, or operationally challenging. In such areas, low-carbon gases (biogas and hydrogen) provide flexible, scalable, and locally adapted solutions.

This section analyses the sectors in Kalmar County with high decarbonization challenges, outlines the barriers impeding transition, and identifies opportunities and incentives that can drive low-carbon gas adoption.

Hard-to-Electrify Sectors in Kalmar County

While much of the service sector, buildings, and light mobility can decarbonize via electrification, several energy-intensive or transport-heavy sectors face significant hurdles:

1. **Heavy Road Transport and Logistics**
   - Profile: Kalmar County has a large base of haulage companies and logistics providers supporting agriculture, manufacturing, and trade.
   - CO_2 emissions: The transport sector accounts for roughly one-third of regional fossil fuel use, dominated by diesel consumption in long-haul trucks.
   - Challenges:
     - Battery-electric solutions are limited by range, weight, and charging time.
     - Hauliers require high reliability and rapid refueling, which low-carbon gases (biogas as LBG/CBG, hydrogen for fuel-cell trucks) can provide.
2. **Public Transport and Municipal Fleets**
   - Profile: Kalmar Länstrafik has long operated biogas buses. Municipal services (waste collection, maintenance) also rely on heavy vehicles.
   - CO_2 emissions: Local authority fleets contribute to urban emissions, though partly mitigated by early biogas adoption.
   - Challenges: Scaling infrastructure for a fully fossil-free fleet, ensuring cost-competitiveness compared to diesel and HVO.
3. **Agriculture and Food Industry**
   - Profile: Kalmar County is one of Sweden's leading agricultural regions, with intensive livestock farming, dairy, and food processing.
   - CO_2 emissions: Significant methane from manure, energy use in food industries, and diesel for machinery and transport.
   - Challenges: Limited electrification options for mobile machinery and process heat. Biogas addresses both waste management and energy needs, while hydrogen may serve as a future fuel for high-temperature processes.
4. **Energy-Intensive Industry (Glass, Foundries, Breweries)**
   - Profile: Smaller-scale industries such as glassworks, foundries, and Åbro Brewery require stable, high-temperature heat.

- CO_2 emissions: Fossil fuels (LPG, oil, natural gas substitutes) are currently used for process heat.
- Challenges: Direct electrification of high-temperature furnaces is costly and sometimes technically unproven. Hydrogen or biomethane are viable low-carbon substitutes.

5. Shipping and Ports

- Profile: Regional ports (Kalmar municipality, Oskarshamn municipality, smaller harbours) support fishing, tourism, and some industrial activities.
- CO_2 emissions: Maritime transport relies on diesel and bunker fuels.
- Challenges: Electrification feasible for ferries or short-sea shipping but not larger vessels. Hydrogen-derived e-fuels or biogas-based LNG alternatives are potential long-term solutions.

6. Energy Security and Backup Supply

- Profile: Hospitals, water utilities, and critical services require resilient backup energy.
- Challenges: Diesel generators dominate today; replacing them with biogas or hydrogen systems enhances resilience without fossil fuels.

Barriers and Challenges

1. **Technical Barriers**
   - Infrastructure gaps: Limited number of refuelling stations (two hydrogen stations under development, few liquefied biogas (LBG) stations).
   - Efficiency losses: Hydrogen production and reconversion involve significant energy losses compared to direct electrification.
   - Technology maturity: Hydrogen in particular is still at pilot stage; equipment supply chains are global and fragile.
2. **Economic Barriers**
   - High investment costs: Electrolysers, liquefaction plants, and storage systems require large upfront capital.
   - Market immaturity: Few end-users create a "chicken-and-egg" problem for both hydrogen and biogas expansion.
   - Price competition: Fossil fuels and liquid biofuels (HVO, biodiesel) remain cheaper and easier to integrate in the short term.
3. **Regulatory and Policy Barriers**
   - Complex permitting: Biogas projects face lengthy approval processes; hydrogen faces uncertainties in legal frameworks.
   - Inconsistent incentives: EU procurement rules sometimes disfavour biogas, while national hydrogen strategy is still under development.
   - Taxation and support volatility: Investors highlight uncertainty around long-term tax exemptions and subsidies.
4. **Social and Acceptance Barriers**
   - Local concerns: Odor issues linked to biogas plants; safety concerns around hydrogen handling.
   - Knowledge gaps: Limited awareness among citizens and SMEs about benefits and applications.

Opportunities and Potential

- **Biogas – Regional Circular Economy Champion**
  - Abundant agricultural residues provide a strategic feedstock base.
  - Digestate use improves soil health and reduces fertilizer imports.
  - Technical studies estimate potential for >500 GWh annual production, covering ~50% of transport fuel needs in the region.
  - Biogas supports job creation and strengthens the rural economy.

- **Hydrogen – Emerging Strategic Solution**
  - Access to renewable energy (wind, solar) and nuclear power at OKG enables both green and pink hydrogen production, ensuring stability and scalability.
  - Two new refuelling stations (Kalmar municipality and Oskarshamn municipality) will establish first-user networks.
  - Pilot projects (municipal fleets, industrial furnaces, backup systems) can demonstrate viability and lower costs.
  - Potential synergies with district heating by using electrolysis waste heat.

- **Sector-Specific Opportunities**
  - Heavy transport: Early adoption of liquefied biogas (LBG)/compressed biogas (CBG) and hydrogen fuel-cell trucks can decarbonize freight corridors.
  - Industry: Glass and foundries can switch to hydrogen combustion, breweries to biomethane.
  - Agriculture: Farmers become both energy producers (biogas) and consumers (biogas for tractors, hydrogen machinery).
  - Critical infrastructure: Hydrogen or biogas backup solutions enhance resilience of hospitals and utilities.

- **Policy and Cooperation Leverage**
  - Fossil-free 2030 target: A strong political driver ensuring alignment of local policies.
  - EU funding (Interreg, ERUF) and national programs (Klimatklivet, Electrification Pilots) provide financial incentives.
  - Regional collaboration platforms: Combining municipalities, energy companies, farms, and SMEs into coordinated clusters reduces risks and accelerates investment.

Kalmar County illustrates the complementary strengths of biogas and hydrogen as enablers of decarbonization in hard-to-electrify sectors. Biogas already demonstrates practical, circular economy benefits in transport and agriculture, while hydrogen is set to unlock solutions for energy-intensive industry, long-haul transport, and energy security.

7. Low-carbon gases: market and innovation

This section outlines the current and future market for these gases, based on uses, ongoing projects, and business models across the value chain.

Current and Potential Applications

The value chain for low-carbon gases extends from feedstock and production to end-use in transport, industry, agriculture, households, and energy systems.

- **Biogas (including biomethane, CBG, LBG)**
  - **Transport sector**:
    - Kalmar Länstrafik (KLT) operates biogas buses.
    - Biogas used in refuse trucks, municipal fleets, and increasingly in heavy-duty freight as liquefied biogas (LBG).
    - Technical potential: >500 GWh/year, equivalent to ~50% of the county's road transport energy demand.
  - **Industry**:
    - Food and beverage sector (Åbro Brewery, food processing) substituting LPG and natural gas with biogas.
    - Metal and glass industries can use biomethane as process gas.
  - **Agriculture**:
    - Digestate from anaerobic digestion used as biofertilizer, reducing mineral fertilizer imports.
    - Biogas tractors and machinery are emerging niche applications.
  - **Electricity and Heat**:
    - Combined heat and power (CHP) plants using biogas to supply farms, industries, and district heating.
  - **Households and public services**:
    - Municipalities support domestic biogas production for cooking/heating in off-grid rural households.
    - Waste management: biogas closes the loop by valorising organic waste.

- **Hydrogen (green & pink)**
  - **Transport sector**:
    - Fuel-cell buses, trucks, municipal service vehicles, with two hydrogen refuelling stations under construction (Kalmar municipality & Oskarshamn municipality).
    - Long-term potential in shipping (e-fuels, ammonia, hydrogen blending in ports).
  - **Industry**:
    - Glassworks and foundries: hydrogen as combustion gas.
    - Ammonia and fertilizer production (future).
    - Food industry: hydrogen to replace fossil LPG in ovens, dryers, or boilers.
  - **Energy system integration**:
    - Power-to-gas solutions: storage of surplus wind/solar electricity.

        - Backup power for hospitals and critical infrastructure.
        - District heating integration via electrolysis waste heat.
    - **Agriculture**:
        - Potential for hydrogen in farm machinery (tractors, harvesters).
        - Hydrogen-derived ammonia for fertilizer production (medium-to-long term).

Projects: Innovation, Research and Productive Applications

Several projects are underway or planned in Kalmar County, driven by public-private cooperation and EU/national support schemes.

- **Biogas Projects**
    - **Existing plants**: Farm-based digesters, wastewater treatment facilities, and cooperative biogas plants (63 GWh production in 2023).
    - **Expansion projects**:
        - Planned plants leveraging livestock manure (strategic feedstock).
        - Paused or challenged projects: Gasum (Mörbylånga), Falk Biogas (Alböke), reflecting regulatory and local acceptance barriers.
    - **System study (WSP, 2025)**: Estimates potential to expand to >500 GWh/year.
    - **Circular agriculture pilots**: Integration of biogas and nutrient recycling, supported by Region Kalmar County.

- **Hydrogen Projects**
    - **Existing**:
        - **OKG Nuclear Plant (Oskarshamn)** – producing hydrogen since 1992 for cooling generators, now selling surplus externally.
    - **Planned**:
        - **Hydri (ReH2)**: Network of 24 hydrogen refueling stations in Sweden, one in Kalmar municipality (partly wind-powered).
        - **PS Energi**: Hydrogen refuelling station in Oskarshamn (supported by the Swedish Energy Agency's Electrification Pilots).
    - **Pilot projects**:
        - Municipal fleet pilots (waste collection vehicles, service vans).
        - Industrial testing: hydrogen furnaces for local glassworks and foundries.
        - Backup power demonstrations for hospitals and water utilities.
    - **Research & Innovation**:
        - Electrolysis technology adoption (PEM, alkaline), including studies on use of nuclear based "pink hydrogen."
        - Feasibility of combining electrolysis with district heating (using waste heat).
        - Regional cooperation with EU's UNIFHY project, sharing knowledge with partner regions (Spain, Denmark, Ireland, Czechia, Poland).

Business Models: Emerging and Ongoing Approaches

The market for low-carbon gases is shaped by a combination of local feedstock supply, infrastructure needs, industrial demand, and policy frameworks. Several business models are emerging in Kalmar County:

- **Biogas Business Models**
  - **Farm-based cooperative models**
    - Farmers supply manure and receive biofertilizer in return.
    - Joint investments in digesters reduce costs and increase bargaining power.
  - **Public transport anchoring**
    - Kalmar Länstrafik guarantees long-term offtake of biogas for buses, providing demand security for producers.
  - **Industrial substitution contracts**
    - Food & beverage companies (e.g. Åbro Brewery) sign supply agreements with biogas producers to decarbonize operations.
  - **Energy service models**
    - CHP-based contracts where energy providers deliver heat/power/biogas as a service to municipalities or industries.

- **Hydrogen Business Models**
  - **Fuel supply contracts for fleets**
    - Hydrogen suppliers (Hydri, PS Energi) targeting municipal and logistics fleets as anchor customers for refuelling stations.
  - **Industrial symbiosis**
    - OKG nuclear plant as producer, local industry as consumer — leveraging surplus hydrogen in closed regional loops.
  - **Energy balancing services**
    - Electrolysers providing frequency regulation to Svenska Kraftnät[31], creating dual revenue streams (hydrogen sales + grid services).
  - **District heating integration**
    - Business models where electrolysis plants sell both hydrogen and residual heat to municipal energy companies.
  - **EU-supported demonstration clusters**
    - UNIFHY regional cooperation fosters transnational business cases (joint investments, knowledge exchange, policy alignment).

Synthesis: Market Development Potential

Kalmar County's market for low-carbon gases rests on the synergy between mature biogas markets and emerging hydrogen ecosystems:

- **Biogas**: Already commercial, with strong agricultural feedstock base and institutional anchor demand. Market expansion depends on stable policy frameworks, expanded infrastructure, and industrial uptake.
- **Hydrogen**: Early stage but strategically positioned, leveraging renewable electricity, nuclear power, and EU/national strategies. Market development will require pilot projects, public–private partnerships, and initial anchor consumers.

[31] *Svenska Kraftnät (Swedish National Grid) is the government agency responsible for operating and developing Sweden's electricity transmission system and ensuring reliability of the national power supply.*

Together, they provide a balanced and complementary energy portfolio:

- **Biogas**: short-to-medium-term decarbonization, circular resource use.
- **Hydrogen**: long-term flexibility and scalability for hard-to-electrify sectors.

Conclusion

The current and potential market for low-carbon gases in Kalmar County is dynamic, shaped by regional strengths (agriculture, nuclear power, renewable resources) and ambitious policy goals (fossil-free 2030).

- **Uses**: Transport, industry, agriculture, households, and critical infrastructure all present viable applications.
- **Projects**: From farm-based digesters to hydrogen refuelling stations, projects demonstrate strong momentum supported by EU and national programs.
- **Business Models**: Cooperative farming, anchor demand from public fleets, industrial symbiosis, and grid-balancing electrolysers illustrate diverse pathways to commercial sustainability.

8. Financing opportunities

The deployment of biogas and hydrogen in Kalmar County requires significant investment in production, infrastructure, and end-use technologies. Financing models are therefore a decisive factor for market expansion. Both public support instruments and private capital mobilization are essential to overcome high upfront costs, uncertain returns, and regulatory risks.

This section provides an overview of current and potential financing models, including subsidies, loans, and innovative mechanisms, to accelerate the low-carbon gas transition.

Public Financing Instruments

Public authorities play a central role in de-risking investments through grants, subsidies, and loans.

- **National and EU Support Schemes**
  - **Klimatklivet (administered by the Swedish Environmental Protection Agency)**
    - Investment support for climate-friendly technologies, widely used in Kalmar for biogas plants, refueling infrastructure, and vehicles.
    - Grants typically cover 30–65% of capital costs.
  - **Regional Electrification Pilots (administered by the Swedish Energy Agency)**
    - Target heavy transport and hydrogen fueling projects. Example: PS Energi hydrogen refueling station in Oskarshamn received funding.
  - **Interreg Europe & ERUF (European Regional Development Fund)**
    - Support innovation and cross-border cooperation, e.g. the UNIFHY project for biogas/hydrogen ecosystem development.
  - **National Hydrogen Strategy (coordinated by the Swedish Energy Agency)**
    - Will shape future financing instruments for electrolyzer capacity and industrial applications.

- **Regional and Local Support**
  - **Kalmar County**: Co-funds pilot projects and provides strategic support aligned with the fossil-free 2030 goal.
  - **Municipalities**: Facilitate procurement (e.g. biogas buses), which indirectly secures revenue for producers and justifies infrastructure loans.

Private and Market-Based Financing

Private capital is critical for scaling up beyond pilots. Current and emerging mechanisms include:

- **Equity and venture capital**
  - Companies like Hydri (ReH2) attract investors to build national hydrogen refuelling networks.
  - Farmers form cooperatives to share investment risk in biogas plants.
- **Debt financing**
  - Commercial banks increasingly provide green loans but require long-term offtake agreements (e.g. public transport contracts) to secure cash flows. Kommuninvest is also a possible financing route for municipalities. Kommuninvest is a Swedish local

government funding agency that offers loans and financial services to municipalities and regions, often with favourable terms for sustainable investments.

- **Corporate investments**
  - Industries such as Åbro Bryggeri and food processors finance biogas substitution to decarbonize operations.
  - Logistics companies may finance hydrogen truck adoption if fuelling networks are guaranteed.
- **Green bonds and sustainability-linked loans**
  - Potential tools for municipalities or regional utilities to fund infrastructure, aligned with EU taxonomy and ESG criteria.

Blended and Innovative Models

Hybrid approaches combine public support with private investment:

- **Public–Private Partnerships (PPPs)**
  - Refueling stations co-financed by *Klimatklivet* and private operators (Hydri, PS Energi).
  - Municipal procurement of biogas buses guarantees long-term demand, making loans bankable.
- **Regional investment funds or clusters** (recommended in the 2025 evaluation study)
  - Could pool resources from municipalities, SMEs, and regional banks to co-finance small and medium-scale gas projects.
- **Revenue stacking for hydrogen**
  - Electrolyzers generate income from hydrogen sales *and* from providing grid balancing services to Svenska Kraftnät.
- **Carbon credits and certificates**
  - Biogas from manure delivers negative emissions (reducing methane leakage), which could be monetized through voluntary carbon markets.

Future Financing Needs and Models

To achieve full potential (>500 GWh biogas, scalable hydrogen ecosystem), financing models must evolve:

1. **Stable long-term support**: Reduce policy uncertainty around tax exemptions and subsidy continuity.
2. **Dedicated hydrogen funds**: Target early-stage electrolyser deployment like EU's Hydrogen Bank concept.
3. **Circular economy financing**: Incentives for integrating biogas digestate into farming systems, linking energy with food security.
4. **Local green bonds or climate funds**: Allow citizens and regional investors to co-finance infrastructure while benefiting from returns.
5. **Risk-sharing mechanisms**: Loan guarantees or insurance for SMEs and cooperatives entering biogas/hydrogen markets.

9. Conclusions and recommendations

The transition to a fossil-free society in Kalmar County by 2030 places low-carbon gases — biogas and hydrogen — at the center of regional decarbonization efforts. Both gases complement each other: biogas provides immediate, circular economy benefits, while hydrogen opens pathways for sectors that are difficult to electrify and require scalable, long-term solutions.

This section synthesizes findings from the analysis and outlines strategic guidelines and next steps to enhance public policy and accelerate the low-carbon gas ecosystem in Kalmar County.

- **Mature vs. Emerging Pathways**
  - *Biogas*: Established market with ~63 GWh/year production, strong agricultural feedstock base, circular benefits through digestate use, and proven role in public transport and industry. Expansion potential exceeds 500 GWh/year.
  - *Hydrogen*: At an early stage, but with strong potential enabled by renewable electricity and nuclear power (Oskarshamn). Two refuelling stations under construction, several pilot projects underway, and strategic alignment with EU's hydrogen targets.
- **Hard-to-Electrify Sectors**
  - Heavy transport, agriculture, food processing, glass and foundry industries, and shipping are key emitters where electrification is limited. Both biogas and hydrogen can provide cost-effective alternatives.
- **Barriers and Challenges**
  - Infrastructure gaps (limited refuelling stations, upgrading capacity).
  - High capital costs and uncertain profitability.
  - Regulatory complexity and unstable support frameworks.
  - Public acceptance issues (odour, safety concerns).
- **Opportunities and Potential**
  - Strong agricultural base enables circular bioeconomy.
  - Oskarshamn's nuclear plant and growing wind/solar base allow unique "green + pink" hydrogen production.
  - Public procurement (e.g., biogas buses) anchors demand and stabilizes investments.
  - EU and national support schemes (Klimatklivet, Interreg, ERUF) de-risk projects.

Strategic Recommendations

Based on the above findings, the following guidelines are proposed to strengthen Kalmar's low-carbon gas ecosystem and support effective public policy:

- **Policy and Regulatory Framework**
  - Simplify permitting and licensing for gas projects, with regional fast-track mechanisms for biogas and hydrogen.
  - Secure long-term financial stability: ensure predictable taxation rules and stable subsidies beyond project cycles.
  - Align regional procurement rules with EU taxonomy, ensuring that biogas is not disadvantaged in public tenders.

- **Infrastructure and Market Development**
  - Expand fuelling and distribution networks for both LBG and hydrogen, prioritizing freight corridors, ports, and rural areas.
  - Promote integrated infrastructure models (hydrogen + district heating, biogas + fertilizer logistics) to maximize efficiency.
  - Support local value chains by encouraging partnerships between farms, industries, and municipalities.
- **Innovation and Competence**
  - Establish a regional competence centre on low-carbon gases, bridging academia, SMEs, and public authorities.
  - Support demonstration projects (hydrogen trucks, industrial furnaces, biogas-based CHP for farms) as references for wider adoption.
  - Promote digital and smart energy solutions to optimize gas production, distribution, and use in interaction with the electricity grid.
- **Social Acceptance and Engagement**
  - Increase communication and transparency: public campaigns on safety, climate benefits, and success stories.
  - Engage citizens and SMEs via participatory financing models (green bonds, cooperative shares).
  - Highlight co-benefits: jobs, rural development, and improved energy security.

Next Steps: Roadmap for Policy and Action

To transform strategic recommendations into tangible results, a phased roadmap of actions is proposed:

Short-Term (2025–2027)

- Finalize and open the two planned hydrogen refuelling stations in Kalmar municipality and Oskarshamn municipality.
- Expand biogas production through cooperative farm projects.
- Launch a regional low-carbon gas platform for coordination among municipalities, industry, and academia.
- Implement information campaigns on hydrogen safety and biogas circularity.

Medium-Term (2027–2030)

- Scale hydrogen production linked to renewable electricity and nuclear power.
- Build additional fuelling stations along key freight corridors and near ports.
- Deploy industrial pilots in glassworks, foundries, and breweries using hydrogen and biogas.
- Integrate biogas digestate fully into regional nutrient cycles with support from agricultural policy.

Long-Term (2030 and beyond)

- Establish Kalmar County as a regional hub for combined biogas and hydrogen ecosystems, serving both domestic and export markets.
- Explore production of e-fuels (ammonia, methanol) for shipping.
- Position Kalmar County within EU hydrogen corridors and cross-border gas markets.

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