


Taking Action on Climate Change, Together

3-NOP and Enteric Methane Reduction

Todd Armstrong, PhD, MBA; November 28, 2018

The sector must find a way to nourish a growing population in a sustainable way

Societal Drivers

- Growing population
- Growing need for food
- Increased income
- Greenhouse gas (GHG) emissions from growing agriculture sector
- Increased demand for animal protein

Market Drivers

- Growing demand for sustainable brands/foods among consumers
- Retail and food value chain sustainability continuous improvement targets
- Recognition of livestock's role in regenerative agriculture
- Urgency to reduce GHG emissions
- Plant proteins

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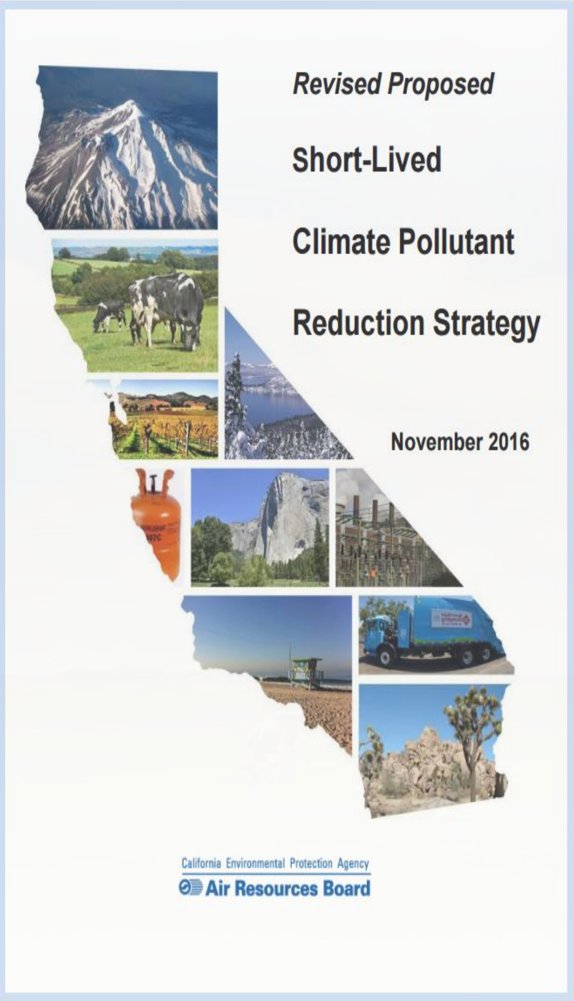
SB 1383 requires California's Air Resource Board to begin implementing methane reductions by Jan 1, 2018



Statewide 2030 Targets for GHG Reductions Below 1990 Levels

40%	40%	50%
Reduction in methane emissions*	Reduction in F-gases	Reduction in black carbon

*Livestock and dairy manure emissions industry-wide, not by individual operation

- ✓ SLCP emission reductions to be accelerated through regulations, incentives, and other market-supporting activities
- ✓ No regulations until January 1, 2024
- ✓ No enteric reductions until proven and acceptable methods available

A lot of action has been taken already

Renewable Energy

Preventing Deforestation
& Protecting Waterways

Strip Cropping/Cycling

Methane Digesters

Balanced Diets
Protein/Nitrogen/Phosphorous

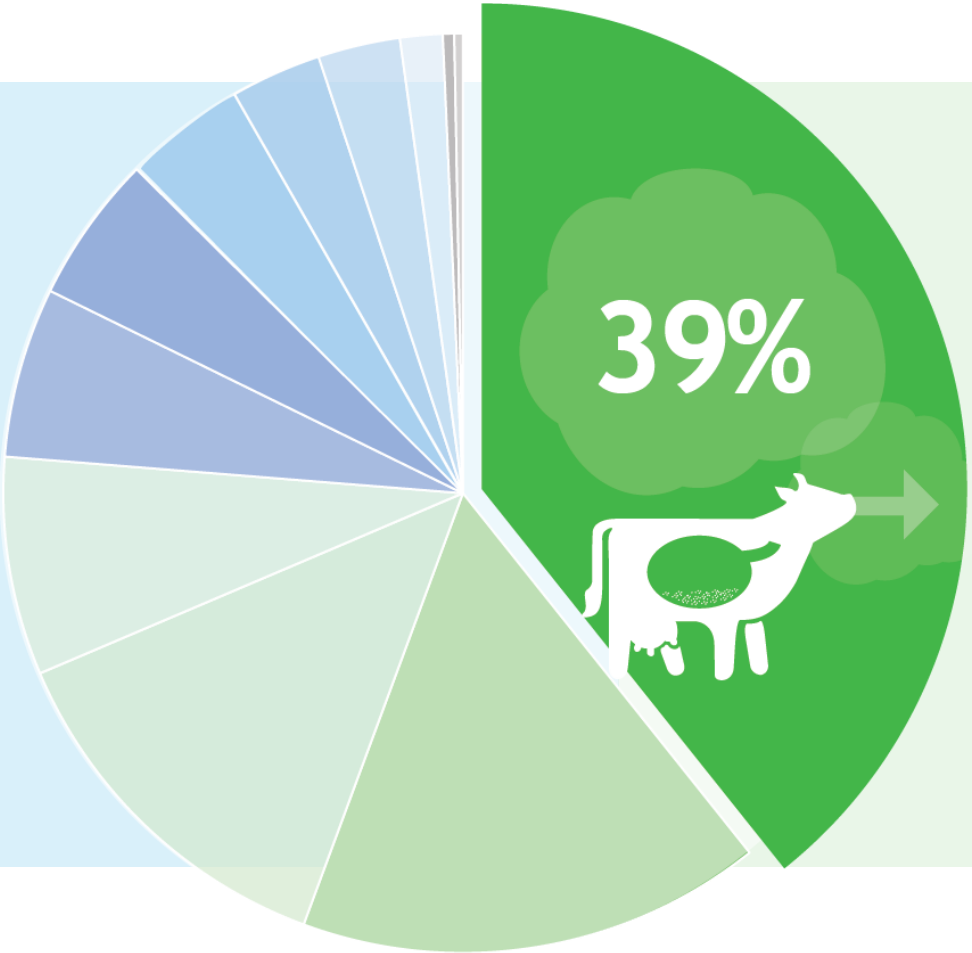
Manure Processing Pits

Manure Water on Fields

Expending Less Energy
Recycling Nitrogen

And there is opportunity to make a greater impact

Current actions don't address all sources of GHG emissions



of livestock GHG emissions

come from enteric (burped) methane[1] which couldn't be addressed until now

Cutting enteric methane production would make a powerful difference in fighting climate change

Source: FAO, Tackling Climate Change through Livestock

DSM took on the challenge to find a solution to reduce enteric methane - a journey of collaboration

Our journey begins in 2008

Recognized the potential impact of reducing enteric methane from ruminants

Product development - strong collaboration

Intense collaboration among scientists, dairy and beef sector/value chain, external partners and experts in nutrition, biology, chemistry, engineering and analytics

~30% methane reduction

Peer-reviewed studies have shown that 3-NOP has the ability to consistently reduce enteric methane by ~30% for dairy, beef and sheep

Today in final stages of development

Brand naming in progress for global launch (3-NOP is the technical name)

Launching in coming years globally

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3-NOP areas of research

- Mode of action
- Efficacy studies for reduction of enteric methane
- Safety studies
  - Animal
  - Human
  - Environment

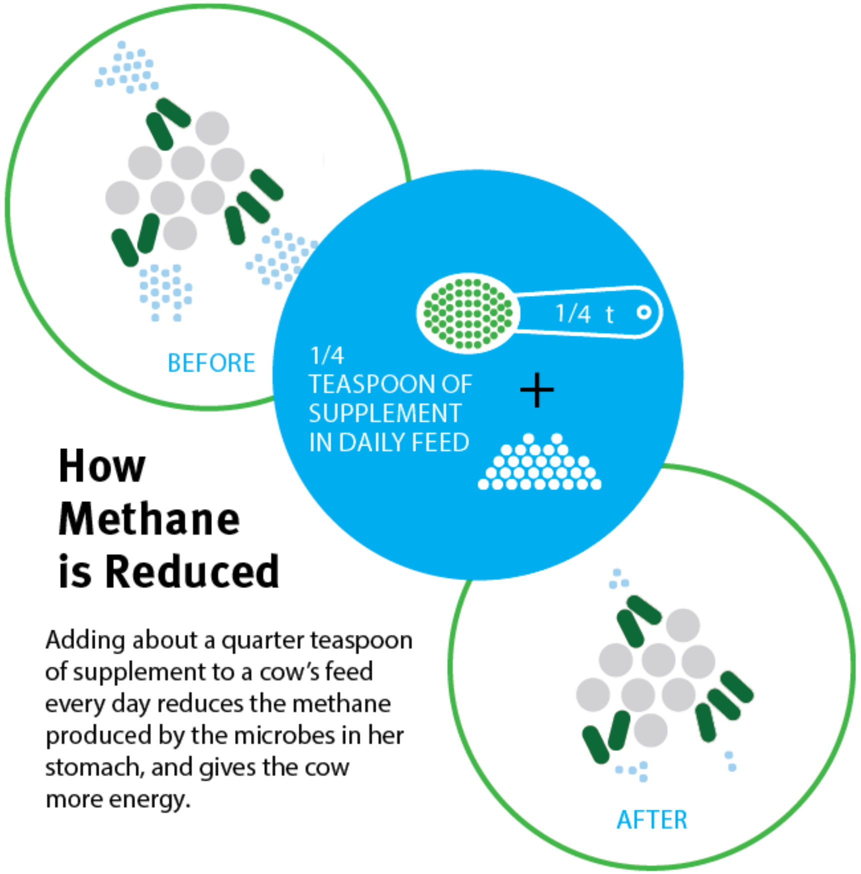
Introducing the 3-NOP feed supplement

Safely broken down in the cow’s digestive system

Mechanism of action
3-NOP works by suppressing the enzyme that triggers enteric methane production

Use in other ruminants
3-NOP can be used with other ruminants, including beef cattle and sheep

Methane reduction begins immediately
Once the animal is fed 3-NOP methane reduction begins immediately, benefits continue with ongoing use



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3-NOP reduces the methane a cow burps

N. Hristov, J. Oh, F. Giallongo, et. al., Proceedings of the National Academy of Sciences 2015, 112, 10663-10668

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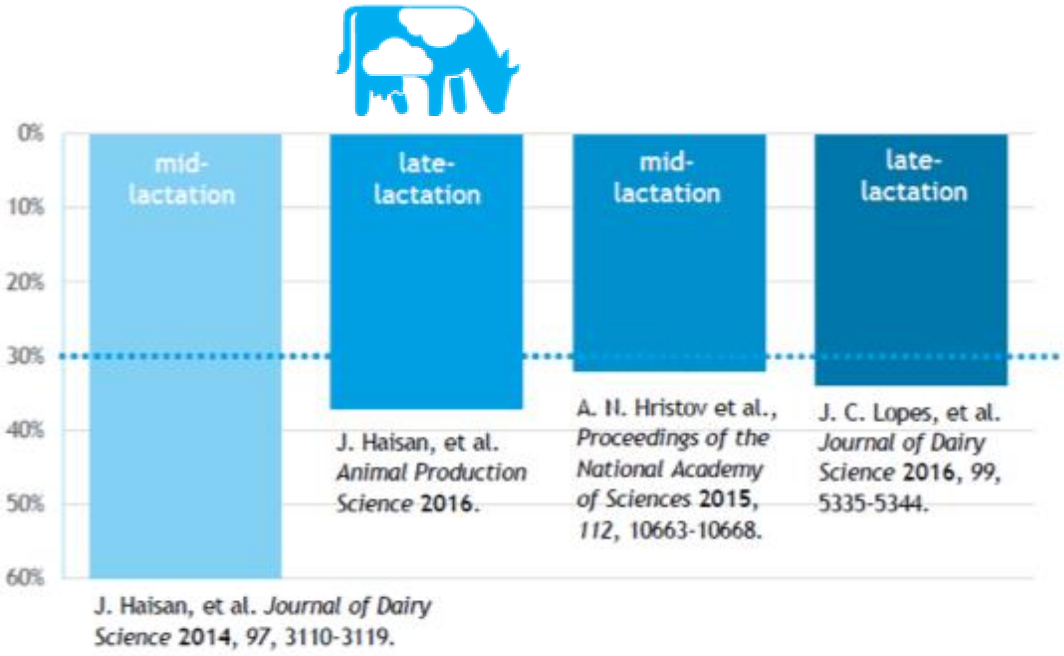
Efficacy and safety studies ongoing

Reduction levels delivered over years of testing

- 20+ on-farm research trials
- 21 peer-reviewed studies published
- Consistent ~30% methane reduction[1]

Working with regulatory authorities globally for product approval

Methane reduction across various studies in dairy cows consuming 3-NOP



1. N. Hristov, J. Oh, F. Giallongo, et. al., Proceedings of the National Academy of Sciences 2015, 112, 10663-10668.

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Total number of published peer-reviewed papers on 3-NOP = 21

1. J. Dijkstra, A. Bannink, J. France, E. Kebreab,S. van Gastelen, *Journal of Dairy Science* , 101 , 9041 – 9047. Antimethanogenic effects of 3-nitrooxypropanol depend on supplementation dose, dietary fiber content, and cattle type.
2. G. Martinez-Fernandez, S. Duval, M. Kindermann, HJ. Schirra HJ, SE. Denman, CS. McSweeney *Frontiers in Microbiology*, **2018**, 9, 15823. NOP vs. Halogenated Compound: Methane Production, Ruminal Fermentation and Microbial Community Response in Forage Fed Cattle.
3. S. Muetzel, R.S. Ronimus, K. Lunn, M. Kindermann, S. Duval, M. Tavendale, An. Feed Science and Technology, **2018**, *244*, 88-92. A small scale rumen incubation system to screen chemical libraries for potential methane inhibitors.
4. D. Vyas, A.W. Alemu, S. M. McGinn, S. M. Duval, M. Kindermann, K. A. Beauchemin; *Journal of Animal Science* **2018**. The combined effects of supplementing monensin and 3-nitrooxypropanol on methane emissions, growth rate, and feed conversion efficiency in beef cattle fed high forage and high grain diets.
5. J. Guyader, E. M. Ungerfeld, K. A. Beauchemin, *Frontiers in Microbiology* **2017**, *8*, 393. Redirection of Metabolic Hydrogen by Inhibiting Methanogenesis in the Rumen Simulation Technique (RUSITEC).
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8. A. Jayanegara, K. A. Sarwono, M. Kondo, H. Matsui, M. Ridla, E. B. Laconi, Nahrowi, *Italian Journal of Animal Science* **2017**, 1-7. Use of 3-nitrooxypropanol as feed additive for mitigating enteric methane emissions from ruminants: a meta-analysis.
9. Vyas, D., McGinn, S. M., Duval, S. M., Kindermann, M. K., Beauchemin, K. A., *Animal Production Science* **2016**. Optimal dose of 3-nitrooxypropanol for decreasing enteric methane emissions from beef cattle fed high-forage and high-grain diets.
10. E. C. Duin, T. Wagner, S. Shima, D. Prakash, B. Cronin, D. R. Yáñez-Ruiz, S. Duval, R. Rümbeli, R. T. Stemmler, R. K. Thauer, M. Kindermann, *Proceedings of the National Academy of Sciences* **2016**, *113*, 6172-6177. Mode of action uncovered for the specific reduction of methane emissions from ruminants by the small molecule 3-NOP.
11. J. C. Lopes, L. F. de Matos, M. T. Harper, F. Giallongo, J. Oh, D. Gruen, S. Ono, M. Kindermann, S. Duval, A. N. Hristov, *Journal of Dairy Science* **2016**, *99*, 5335-5344. Effect of 3-NOP on methane and hydrogen emissions, methane isotopic signature, and ruminal fermentation in dairy cows.
12. D. Vyas, S. M. McGinn, S. M. Duval, M. Kindermann, K. A. Beauchemin, *Journal of Animal Science* **2016**, *94*, 2024-2034. *Effects of sustained reduction of enteric methane emissions with dietary supplementation of 3-nitrooxypropanol on growth performance of growing and finishing beef cattle.*
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14. A. N. Hristov, J. Oh, F. Giallongo, T. Frederick, M. T. Harper, H. Weeks, A. F. Branco, W. J. Price, P. J. Moate, M. H. Deighton, S. R. O. Williams, M. Kindermann, S. Duval, *Journal of Dairy Science*, **2016**, *99*, 5461-5465. *Short communication: Comparison of the GreenFeed system with the sulfur hexafluoride tracer technique for measuring enteric methane emissions from dairy cows.*
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21. G. Martínez-Fernández, L. Abecia, A. Arco, G. Cantalapiedra-Hijar, A. I. Martín-García, E. Molina-Alcaide, M. Kindermann, S. Duval, D. R. Yáñez-Ruiz, *Journal of Dairy Science* **2014**, *97*, 3790-3799. *Effects of ethyl-3-nitrooxy propionate and 3-nitrooxypropanol on ruminal fermentation, microbial abundance, and methane emissions in sheep.*

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Center for Veterinary Medicine Drug Approval Process

5 Major Technical Sections

Effectiveness

Sponsor must show that the product *works in the target animal species* when it is used according to the label

Chemistry, Manufacturing, and Controls

Sponsor details the mfg plan

1. Ensures product is *high-quality and safe*
2. Deciding when FDA *inspects facilities*

Target Animal Safety

1. Identify any *harmful side effects*
2. Establish a *margin of safety*

Human Food Safety

Food products from treated animals are *safe for people*

1. Toxicology
2. Residue chemistry
3. Microbial food safety
4. Analytical method

Environmental Impact

Sponsor prepares an Environmental Assessment that describes *potential environmental effects*

https://www.fda.gov/animalveterinary/resourcesforyou/animalhealthliteracy/ucm219207.htm#puzzle

Minimal expectations for feed additive

- **Clear demonstration of product efficacy**
  - Ideal dose and duration of product
  - Evidence of consistent reduction of enteric methane in various geographies and feeding regimens
- **Establishment of product mode of action**
  - Definition of how product impacts enteric methane
  - Influence on rumen microbial population
- **Complete safety evaluation**
  - Animal
  - Human
  - Environment

By working together we can make a difference

Suppliers

Farmers

Dairy Companies
& Retailers

Consumers

Policy
Makers

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