Trade-offs between methane emission reduction and nitrogen losses

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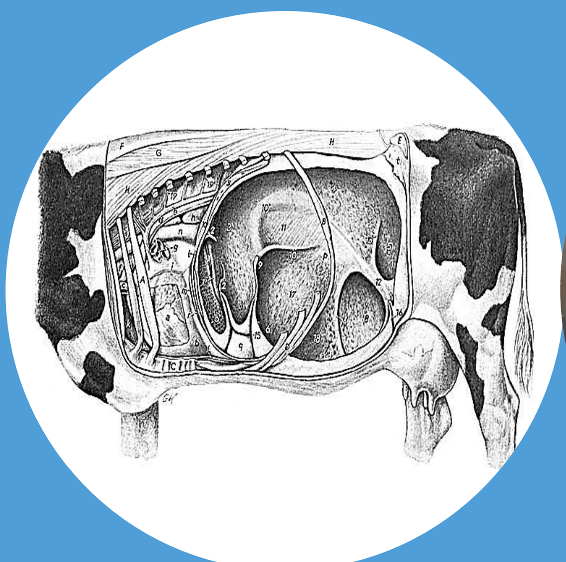


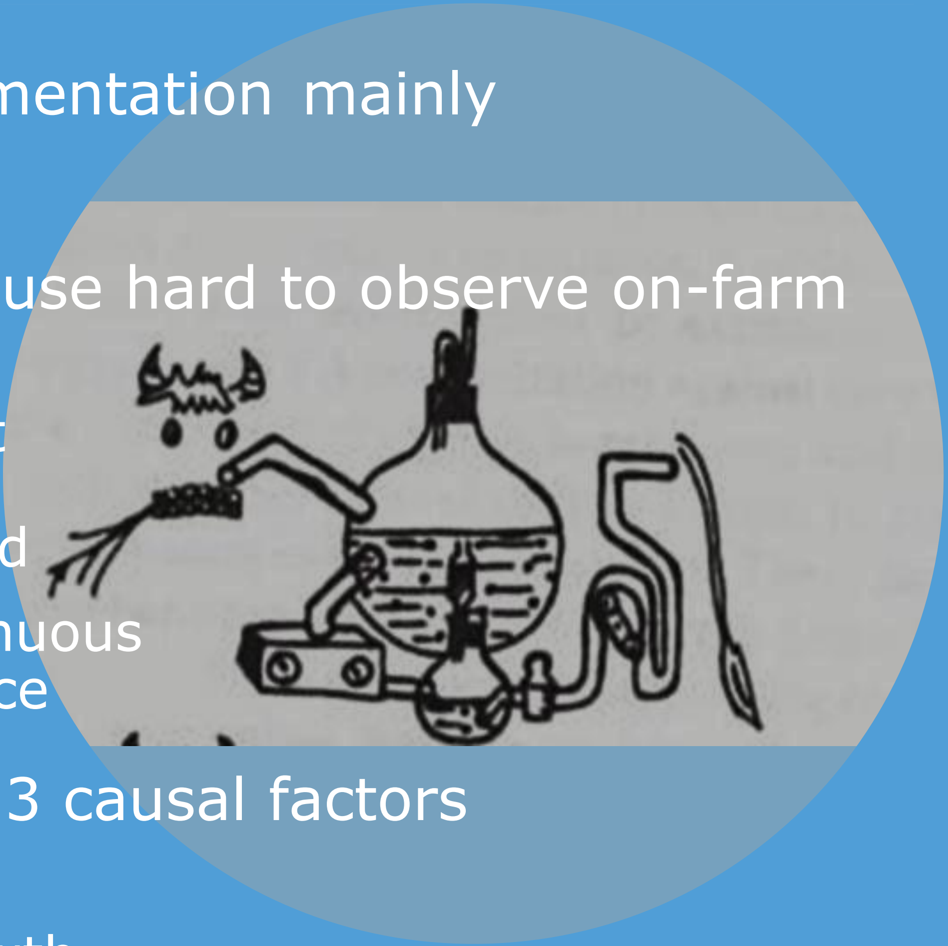
Methane (CH_4) and N excretion, trade-offs

- Trade-offs nutritional measures to reduce enteric CH_4

- At animal level ← this presentation
  - Digestibility feed, feed composition
  - Feed intake, feeding value, animal productivity
- At farm level
  - Manure storage, application (ammonia, indirect N_2O)
  - Soil N emissions (direct N_2O)
  - Soil organic matter sequestration (CO_2)
- External to farm
  - e.g. machinery, transport, deforestation, soils,...

Directing CH_4

- Originates from rumen fermentation mainly (~ 90%)
- Need to calculate CH_4 because hard to observe on-farm
  - CH_4 concentration in air sample measurable, but to direct CH_4 farmer unit g CH_4/cow/d needed
  - Inaccurate and discontinuous measurements in practice
- To calculate CH_4 emission: 3 causal factors
  - OM degradation
  - Efficiency microbial growth
  - Amount and type of VFA formed



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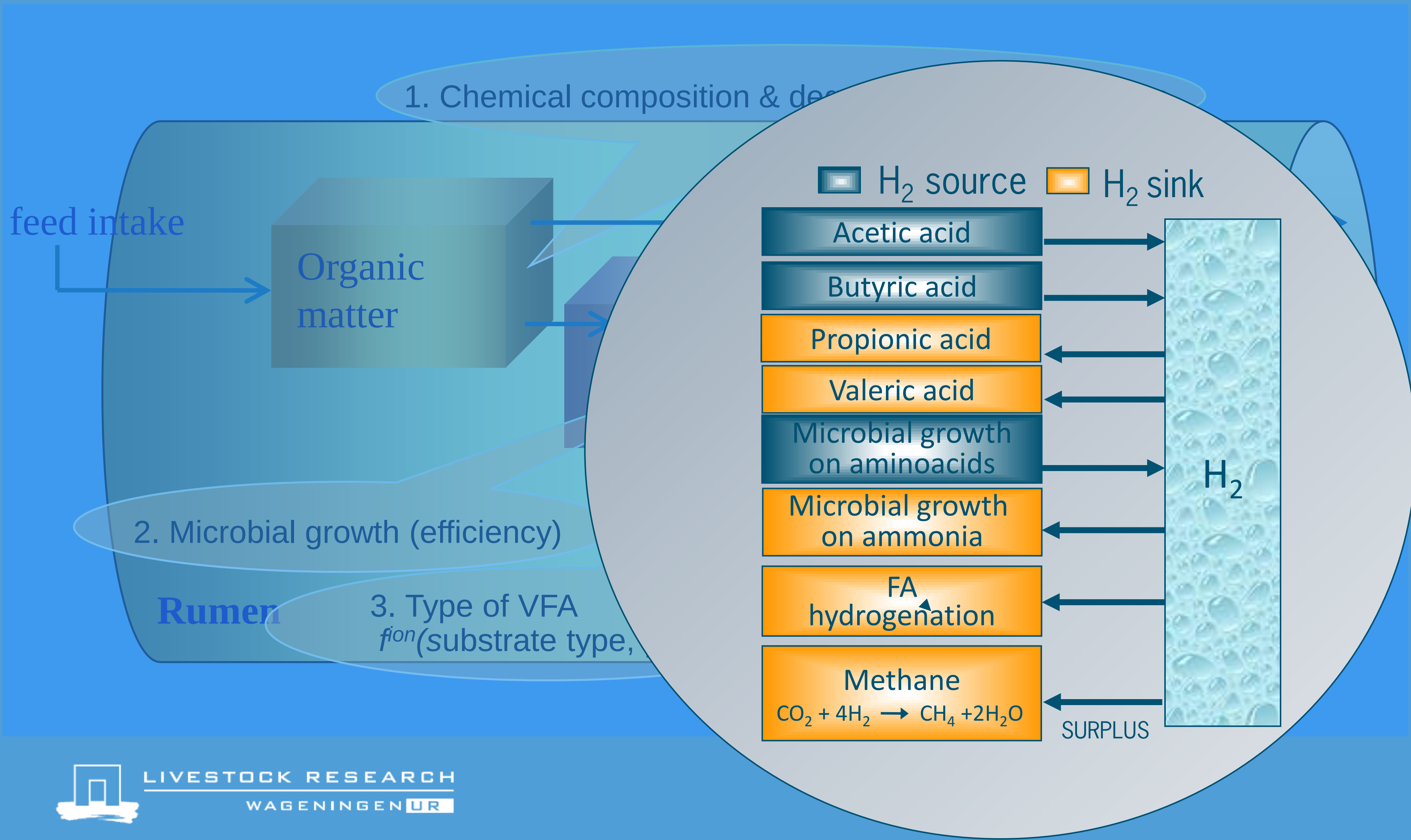
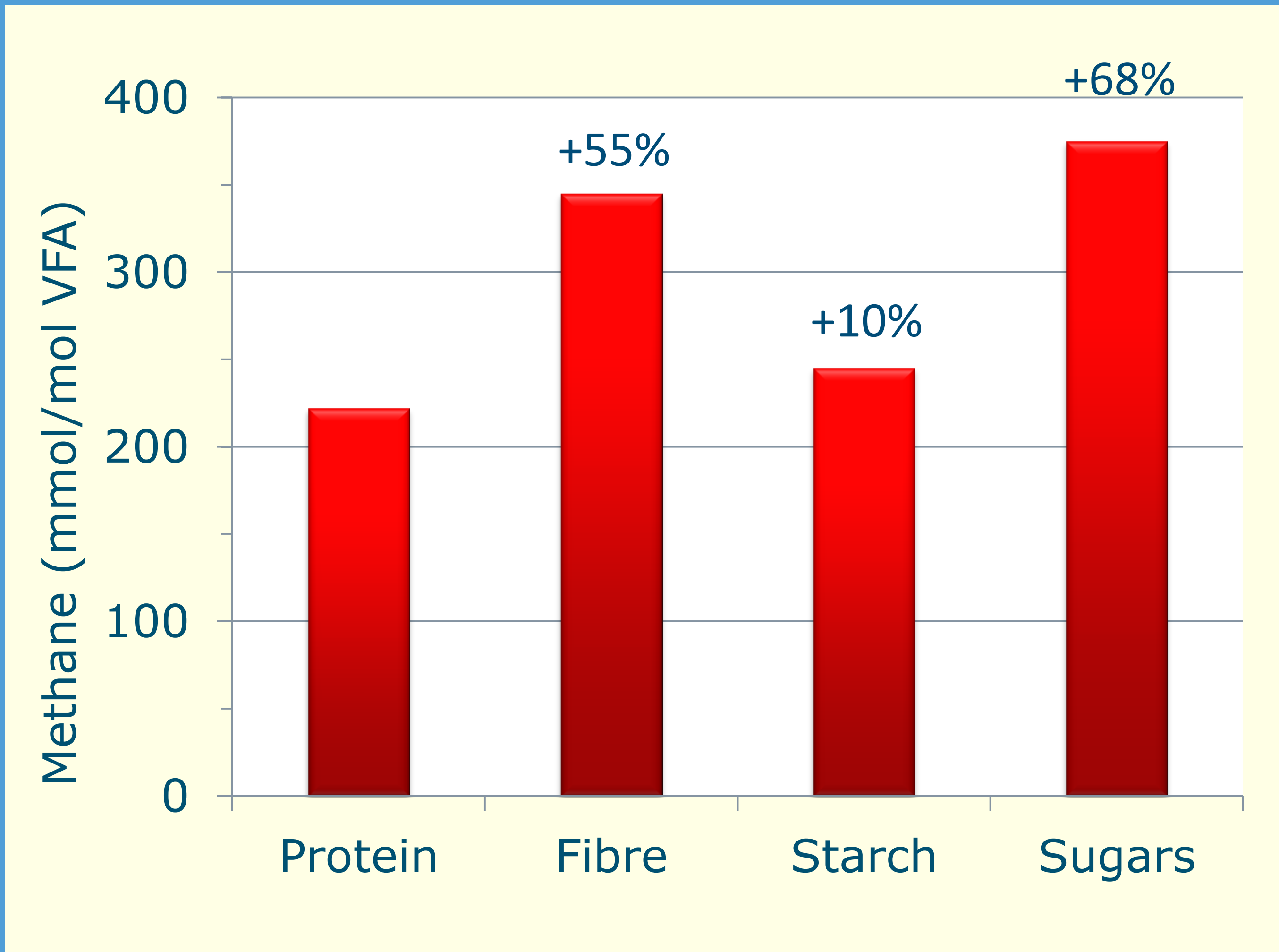
Dietary effects on rumen fermentation
3 causal factors to quantify effects on CH_4



Chemical composition affects CH_4



Fat

no VFA

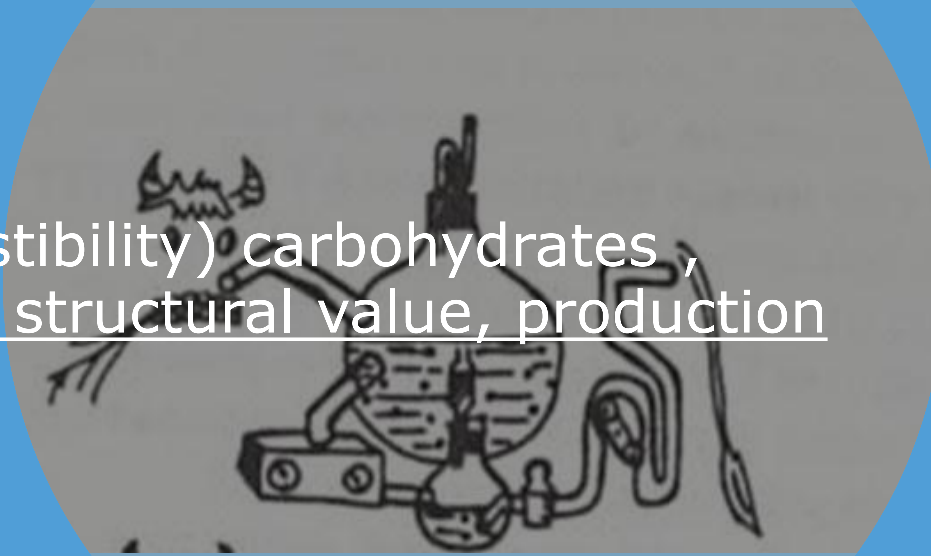
negative CH_4 by hydrogenation unsaturated fat

(small effect)

Meta-analysis in vivo data lactating cows
Bannink *et al* (2006)

Options to reduce CH_4, possible trade-offs

- Reducing rumen fermentable OM,
  without loss of feed intake, (fibre) digestibility, production
  - Include fat
  - Resistant protein & starch
  - Starch for sugar



- Change (composition, digestibility) carbohydrates ,
  without loss of feed intake, structural value, production
  - Starch for sugar and fibre
  - Less fibre, more protein
  - Higher digestibility
- Change feed intake, intraruminal fermentation conditions,
  without loss of feed intake, fibre digestibility, production
  - Higher intake/production, faster fermentation/lower pH

Directing emissions: estimating CH_4
simple or complicated?

- IPCC Tier 2 (1997): CH_4 energy = 6% of gross energy intake
- Regression models: including other (dietary) factors
- Dynamic models: mechanism represented (previous slide)

<u>Inputs</u> required by model	IPCC Tier 2	Regression	Dynamic
Digestibility / NE_L or ME value diet	✓	✓	
NE_L requirement → Feed intake	✓	(✓)	
Feed intake		(✓)	✓
Chemical composition → GE value diet	✓	(✓)	
Chemical composition		✓	✓
Rumen degradation characteristics			✓
Other (empirically available) dietary factors		(✓)	

Estimating 3 causal factors too complicated?

Input types ordered by colour for various models

Inputs required for model :	IPCC Tier 2	Regression	Dynamic
Digestibility / NE_L or ME value diet	✓	✓	
NE_L requirement → Feed intake	✓	(✓)	
Feed intake		(✓)	✓
Chemical composition → GE value diet	✓	(✓)	
Chemical composition		✓	✓
Rumen degradation characteristics			✓
Other (empirically available) dietary factors		(✓)	

- All calculations methods rely on similar input types
- But, inputs different origin and models 'handle' differently
- Model of choice depends on data, aim and detail required

aim = anticipate on-farm,
not general inventories afterwards

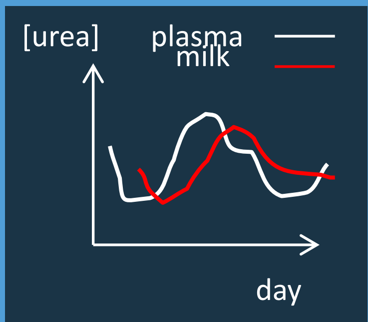
Directing N excretion

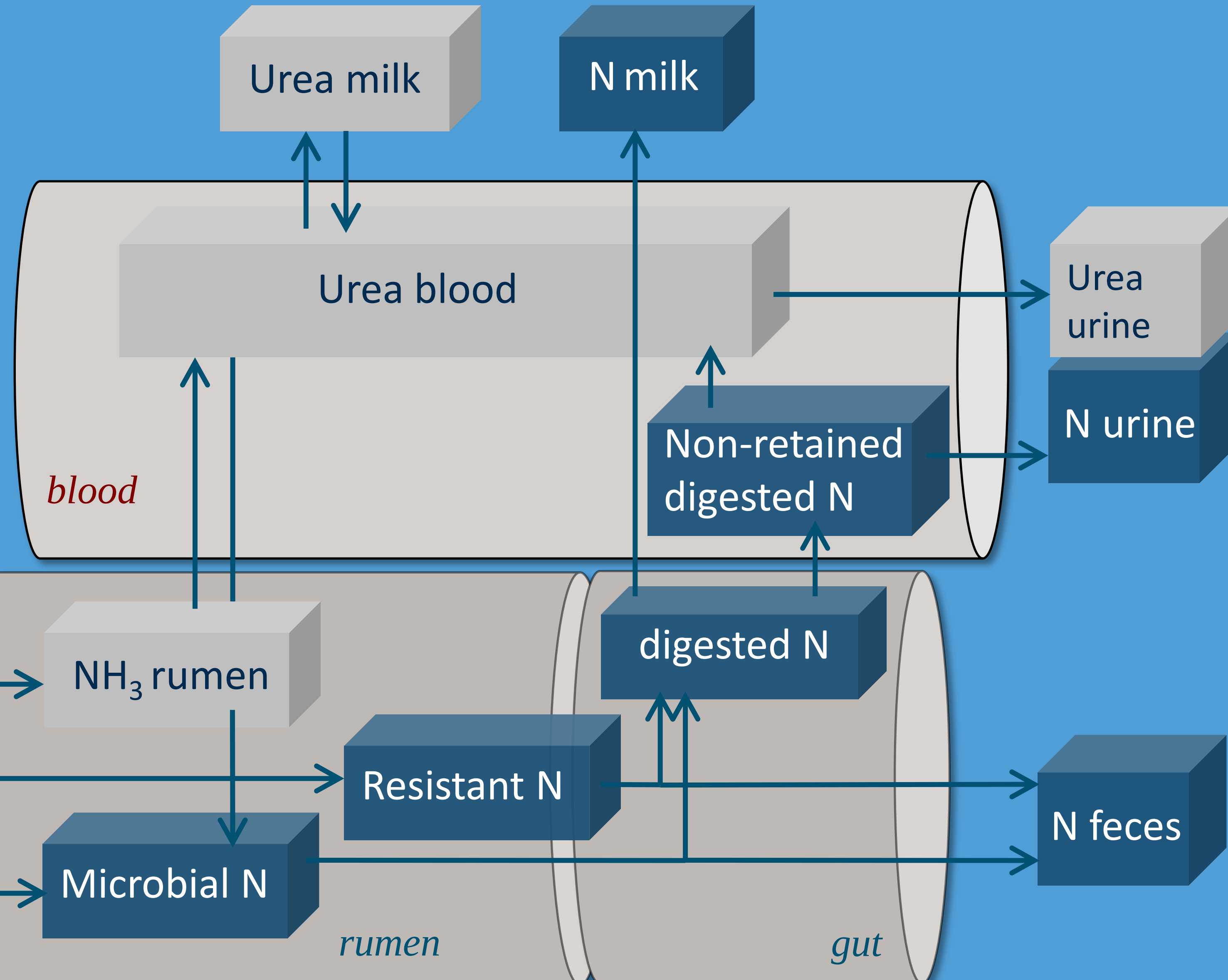
- Mainly depends on N intake & animal productivity
- Again, rumen plays important role
  - Faecal N digestibility
  - Urine (urea) N : Faecal N
  - Recycling urea from blood to rumen
    importance with lower dietary N

- Estimating effects on N excretion
  - By balance calculation

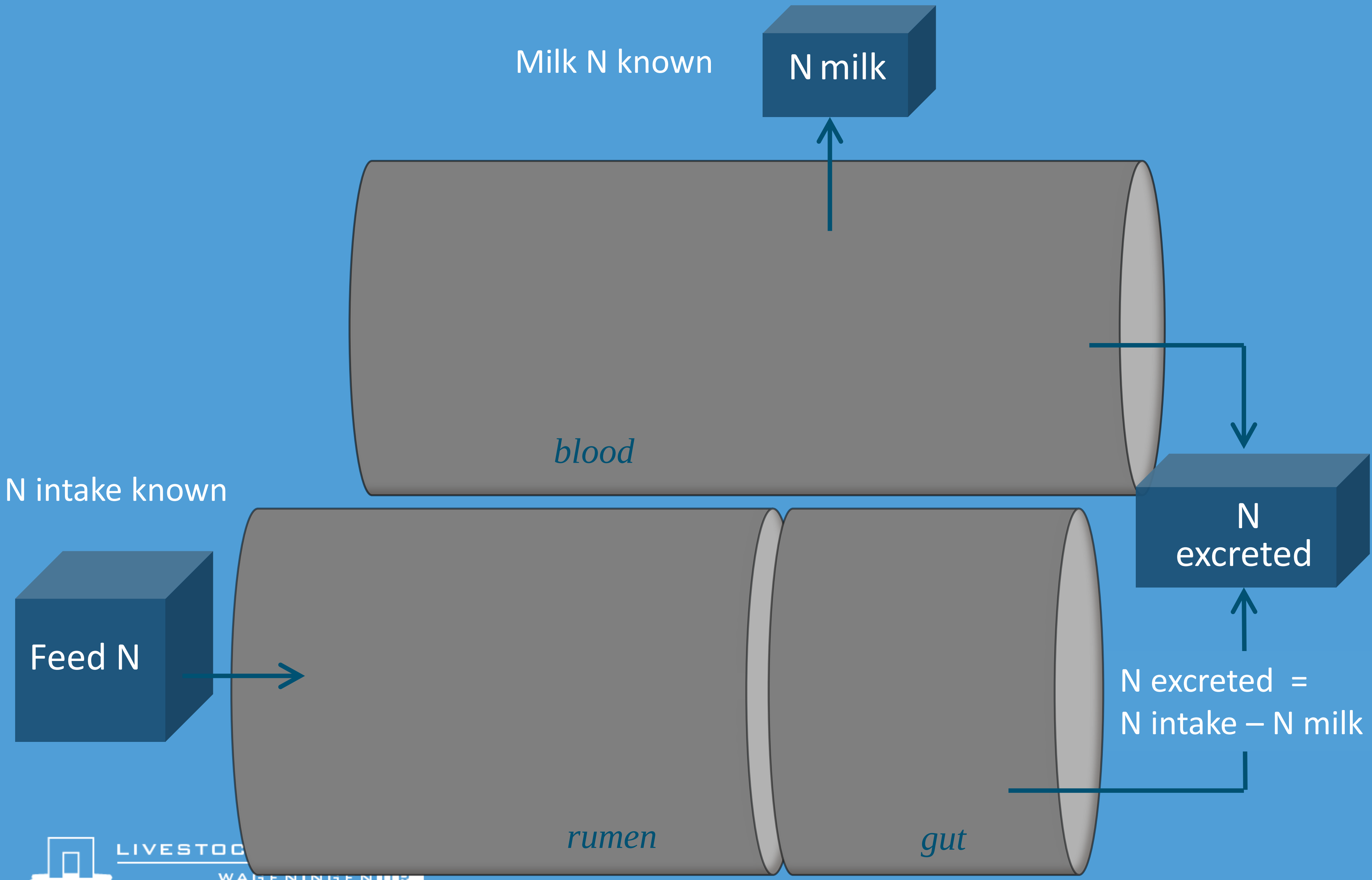
  N excreted = N intake – N animal product
- Estimating N_2O emissions
  - Directly (manure N) or indirectly (ammonia, nitrate)
  - Excreta fouled surfaces, manure storage and application

N and urea flows in cow



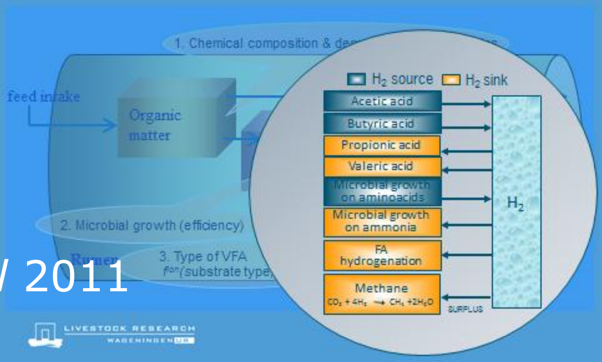


Simplify: calculated N balance



Calculated trade-off CH_4 and N excretion
effects grassland management & nutrition

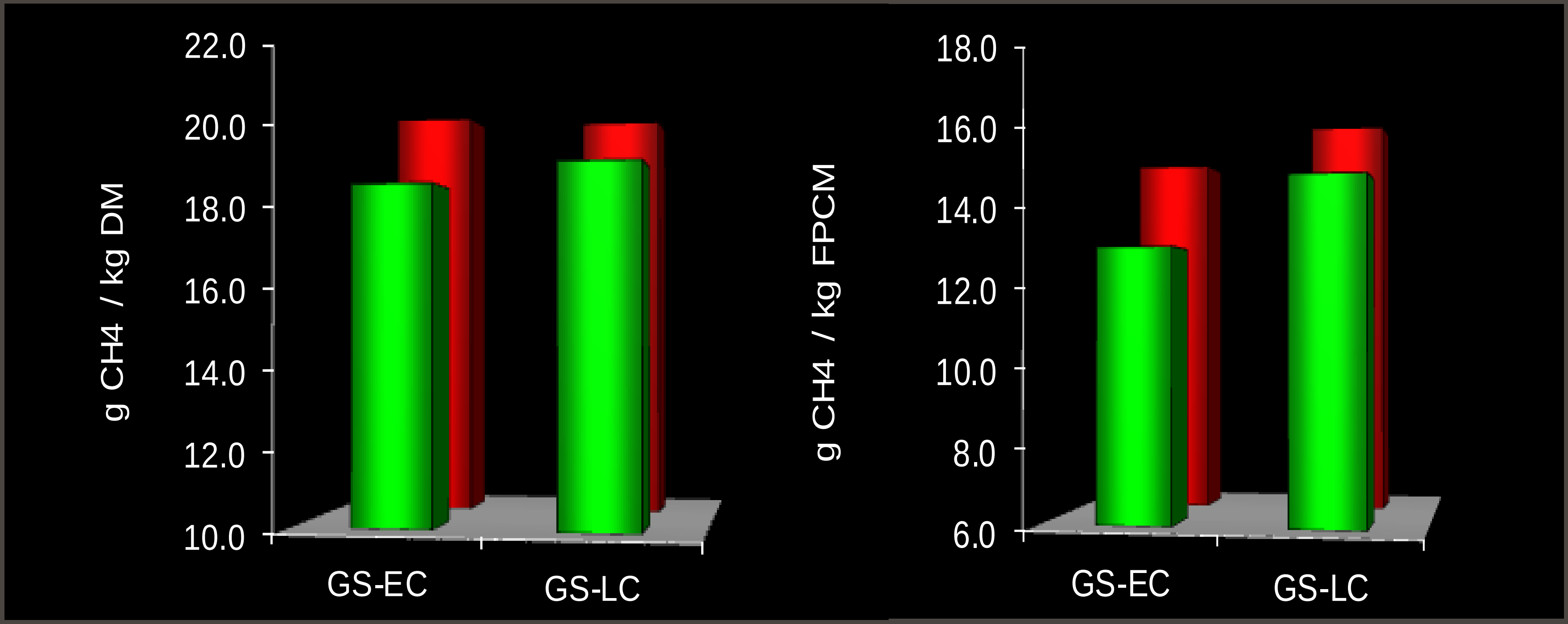
- Simulations with mechanistic 'rumen' model
  (Dutch Tier 3 for enteric CH_4 in cows)
  Dijkstra *et al* 1992; Mills *et al* 2001; Bannink *et al* 2011



- 90% grass diets, with effect of grassland management
  - high (HF) vs. low (LF) fertilized (350 or 150 kg N/ha)
  - early (EC) or late (LC) cut (3000 or 4500 kg DM/ha)
- 40 diets, including same grassland management effects
  - part of grass silage replaced by
    straw; beet pulp; maize silage; potatoes
  - varying feed intake: concentrate level 20% or 40%
  - feed intake according to Dutch feed intake capacity

Effect grassland management on CH_4

18 kg DM/d (90% grass & 10% concentrates)



GH = herbage; GS = grass silage

EC = early cut; LC = late cut

= high N-fertilization = low N-fertilization

Bannink *et al* (2010)

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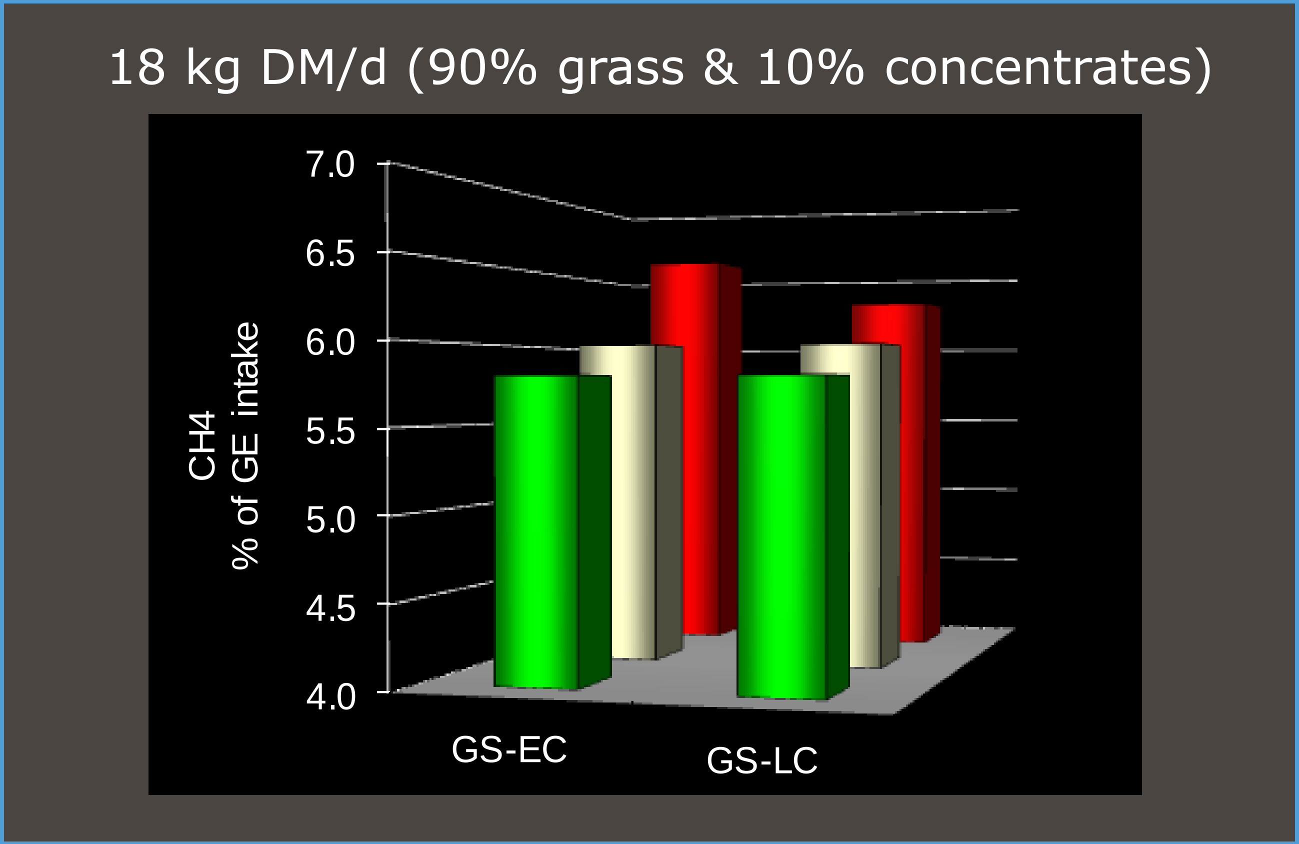
Compared to IPCC Tier 2



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Bannink *et al* (2010)

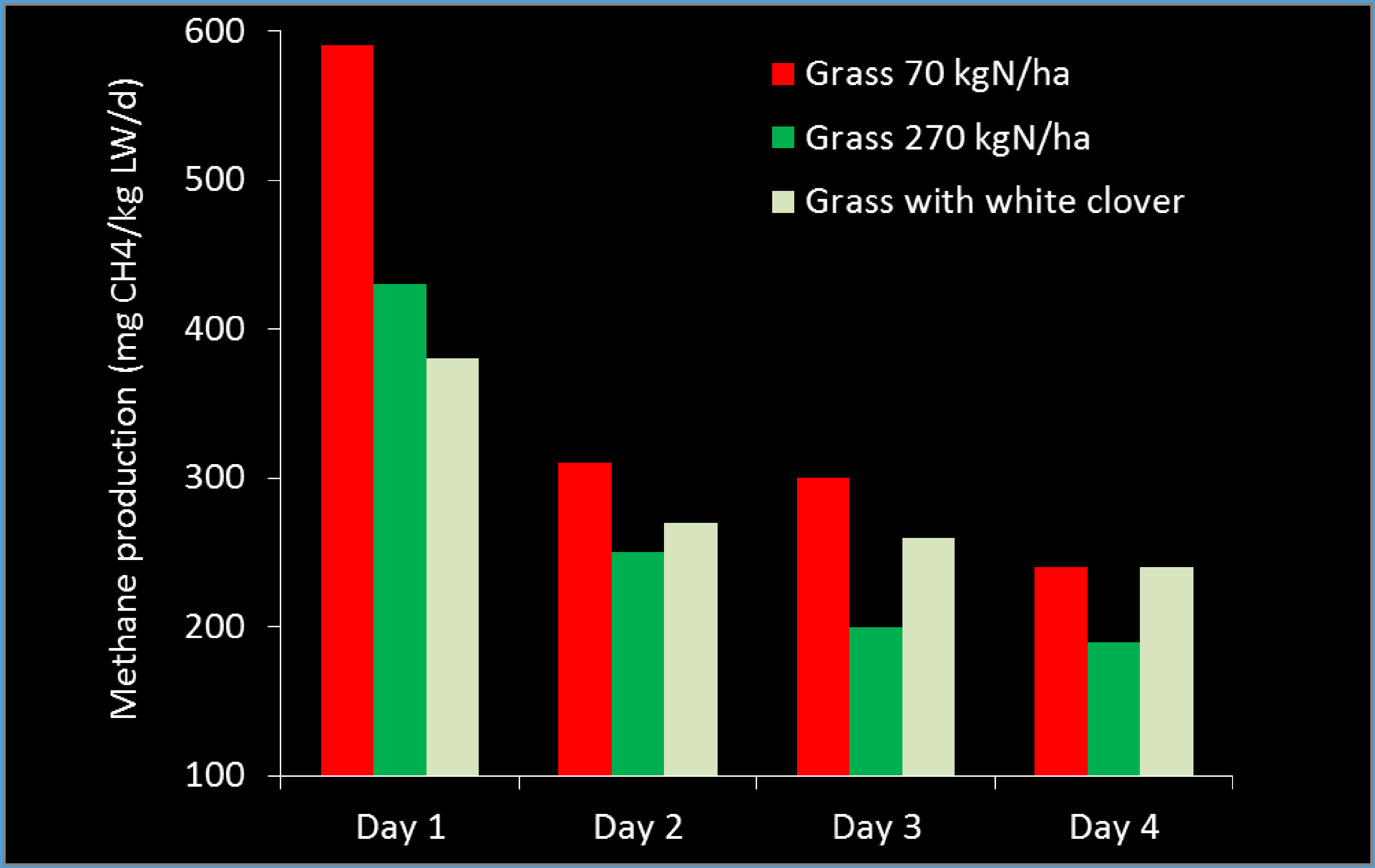
high N-fertilization

low N-fertilization

IPCC Tier 2 default; but updated to 6.5% !

Similar observations reported - 1 -

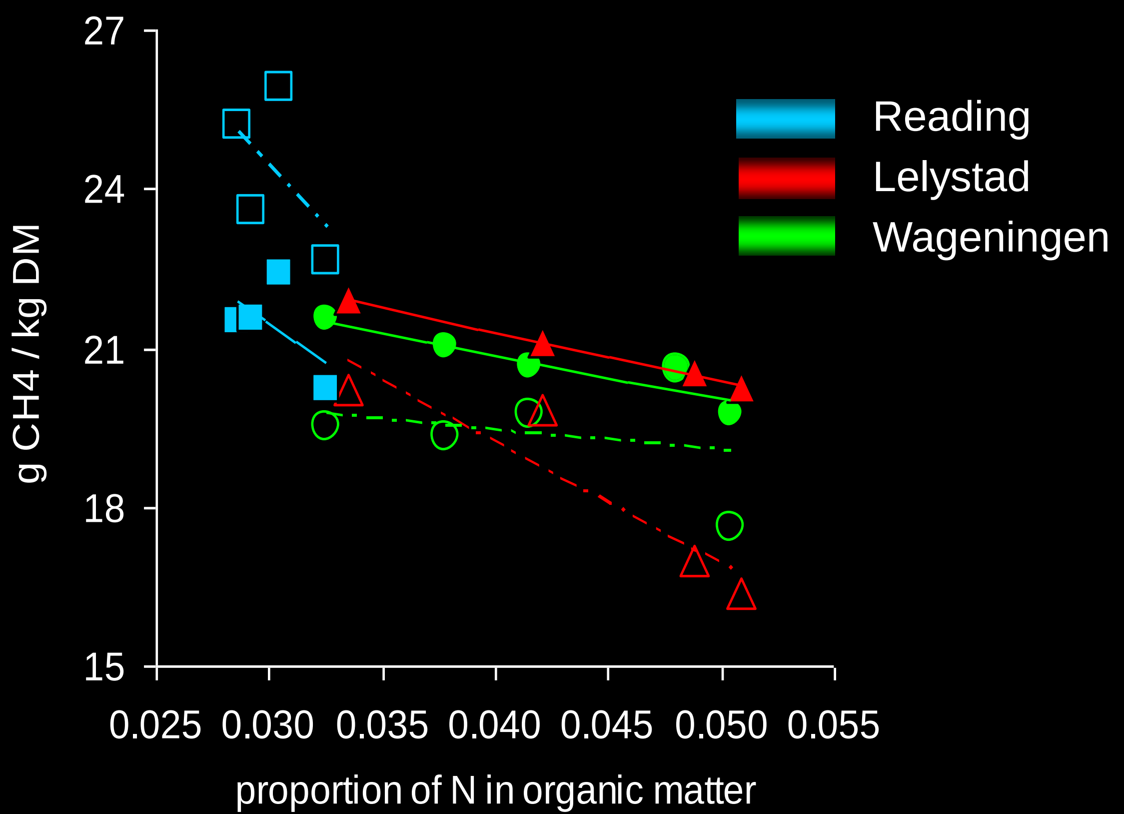
- Murray *et al* 2001; 4-day grazing sheep, grass pasture, tunnels



higher CH_4 per kg sheep LW, with less N fert./ha, clover initially comparable to high fert. grass

Similar observations reported - 2 -

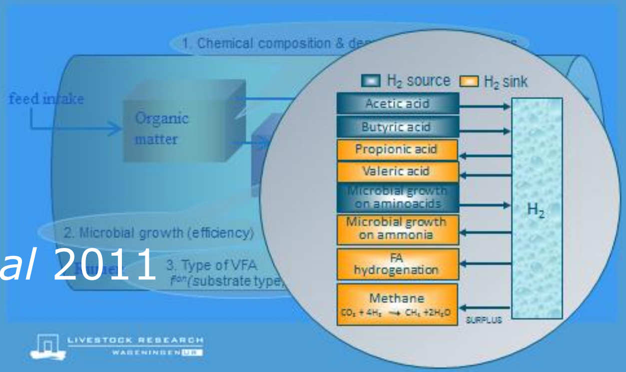
- data grass diets Reading, Lelystad & Wageningen used by Bannink *et al* 2010; cows, grass herbage, chambers



closed symbols = predicted open smbols = observed

Example of trade-off CH_4 and N emission
simulated effects of grassland management

- Simulations with
  mechanistic 'rumen' model
  (Dutch Tier 3 for enteric CH_4 in cows)
  Dijkstra *et al* 1992; Mills *et al* 2001; Bannink *et al* 2011



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    straw, beet pulp, potatoes (15%); maize silage (50%)
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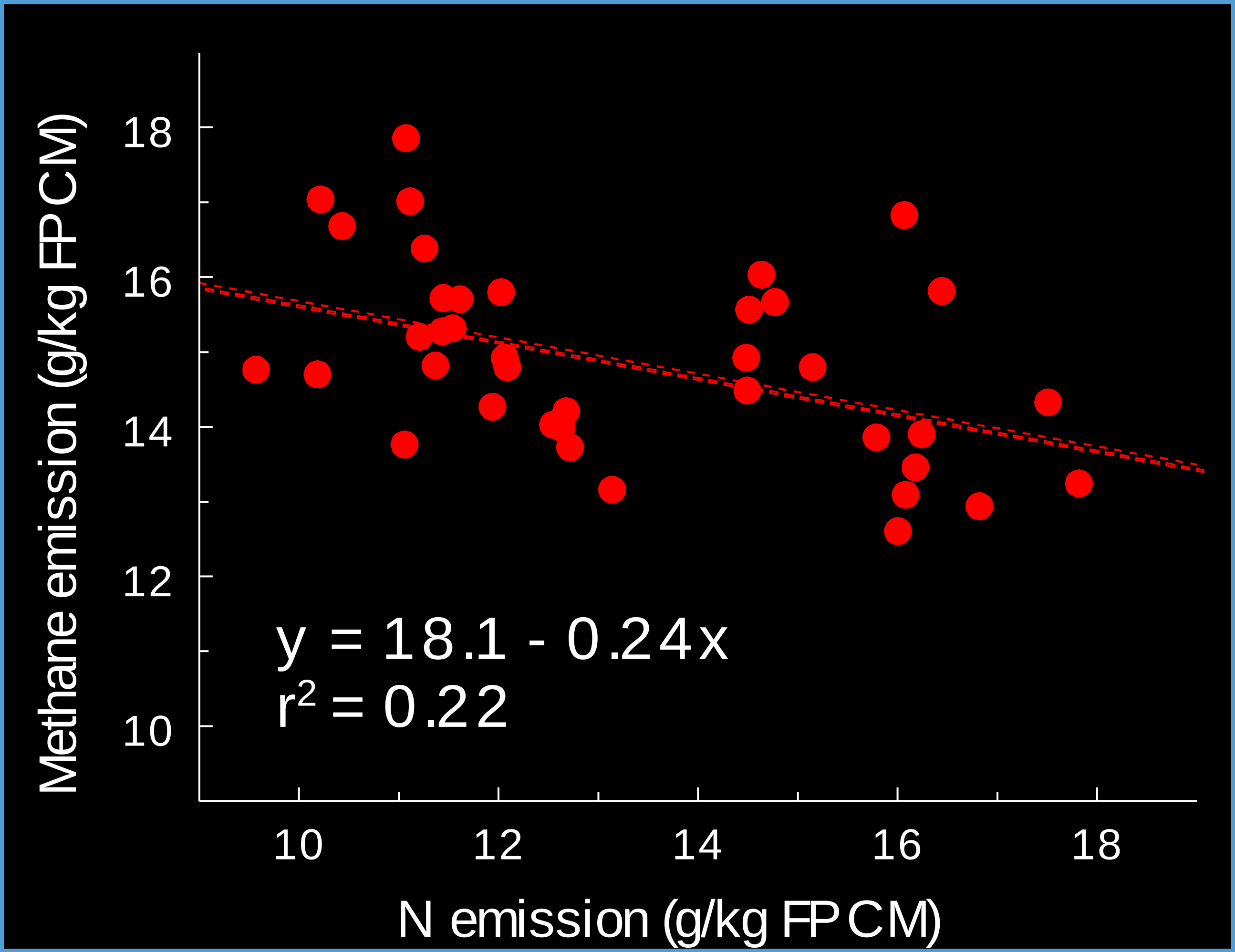
CH_4 vs. N excreted per kg corrected milk



Dijkstra *et al* (2011)

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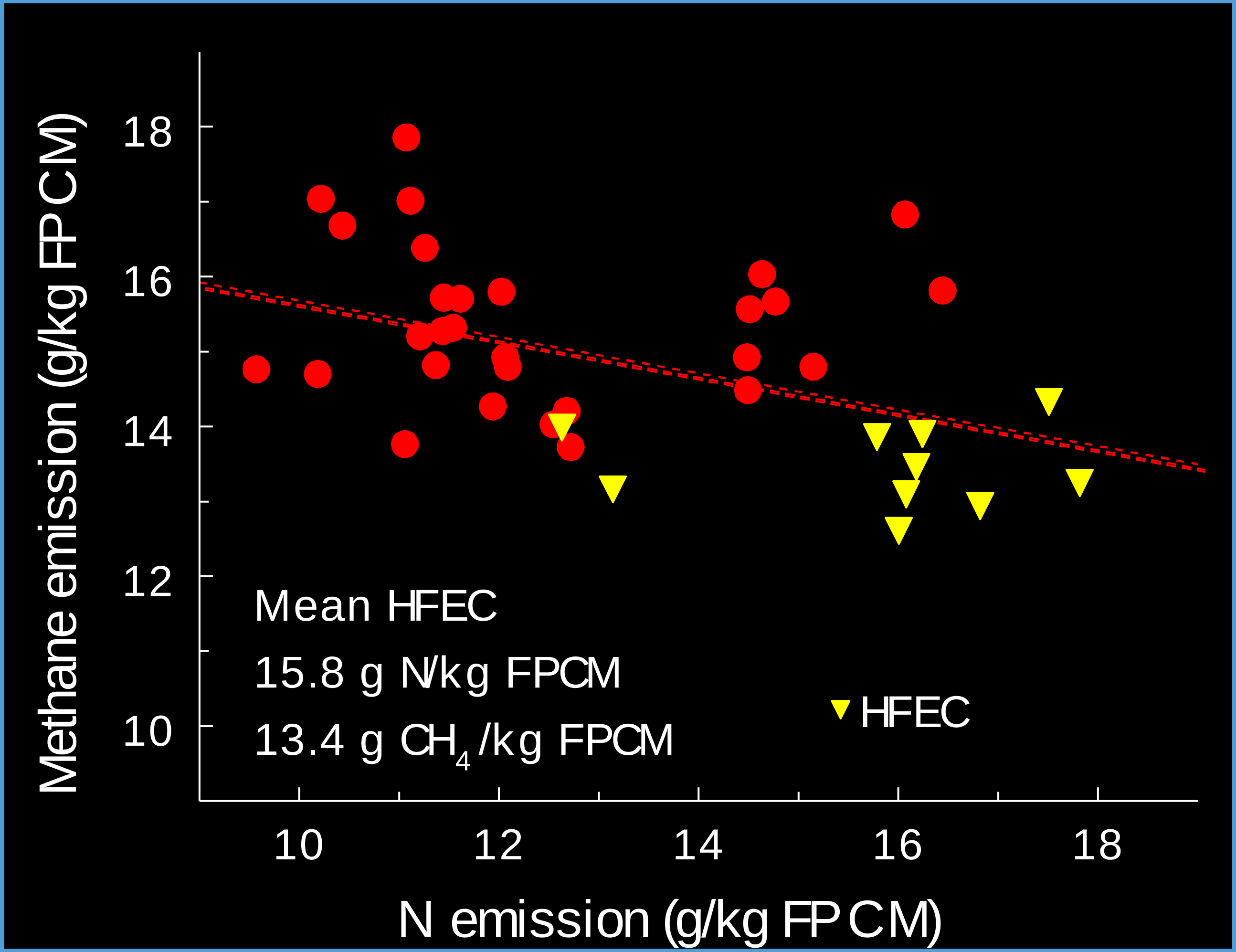

Dijkstra *et al* (2011)

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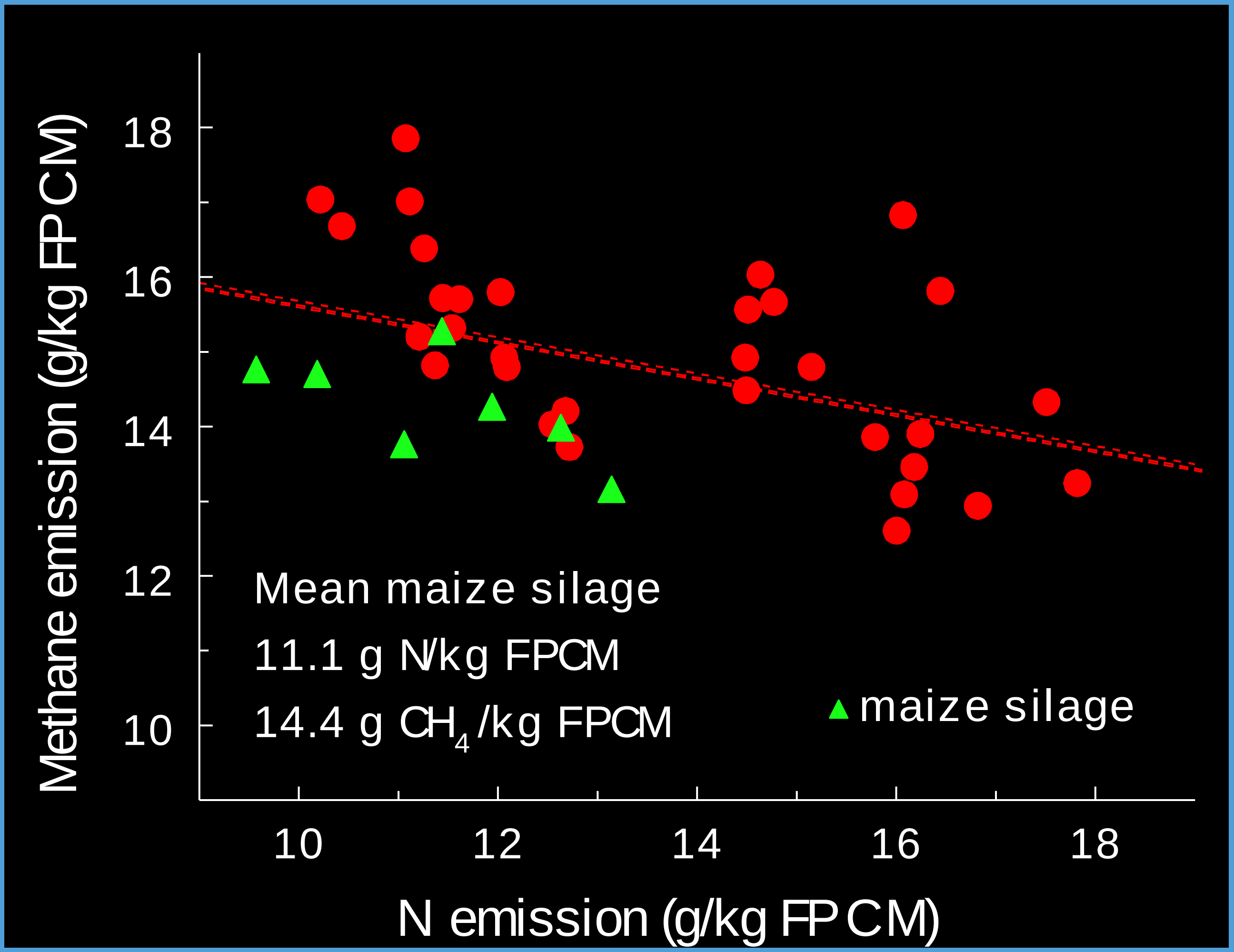


Dijkstra *et al* (2011)

Simulated trade-off CH_4 and N excretion

- Trend of less CH4 with more N excreted per kg corr. milk
- Previous notions in inventories monitoring that lowering farm N surplus generally leads to less GHG questionable

  applies when coming down from extreme N surpluses,
  not for on-farm management

- Simulated general trend indicates (Dijkstra *et al* 2011)

  ↓ 1 g N excreted/kg milk ↑ 0.24 g CH_4/kg milk
  thus, 1 g N ≈ 0.01 g N_2O versus 0.24 g CH_4
  (in addition to direct loss also indirect losses)

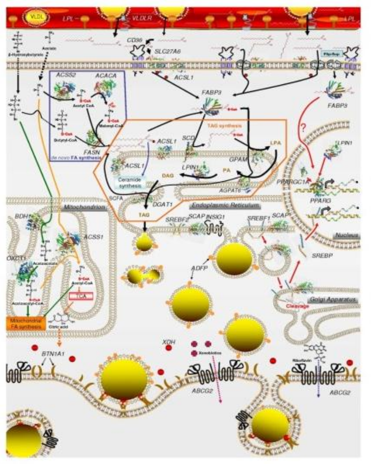
  GWP N_2O : GWP CH_4 = 298 : 25
  thus, less N generally compensated by more CH_4

On-farm monitoring to anticipate

- Most measurements not useful to monitor how to mitigate or prevent
  - Needed the unit quantity/d or flow/d (instead of concentrations)
  - Only concentrations with atmospheric/exhaled air, excreta composition
- Possibility to monitor milk
  - Milk measured accurately as daily flow (in unit L/d)
  - Milk fat composition related to enteric CH_4 ?
  - Milk urea content related to N excretion ?

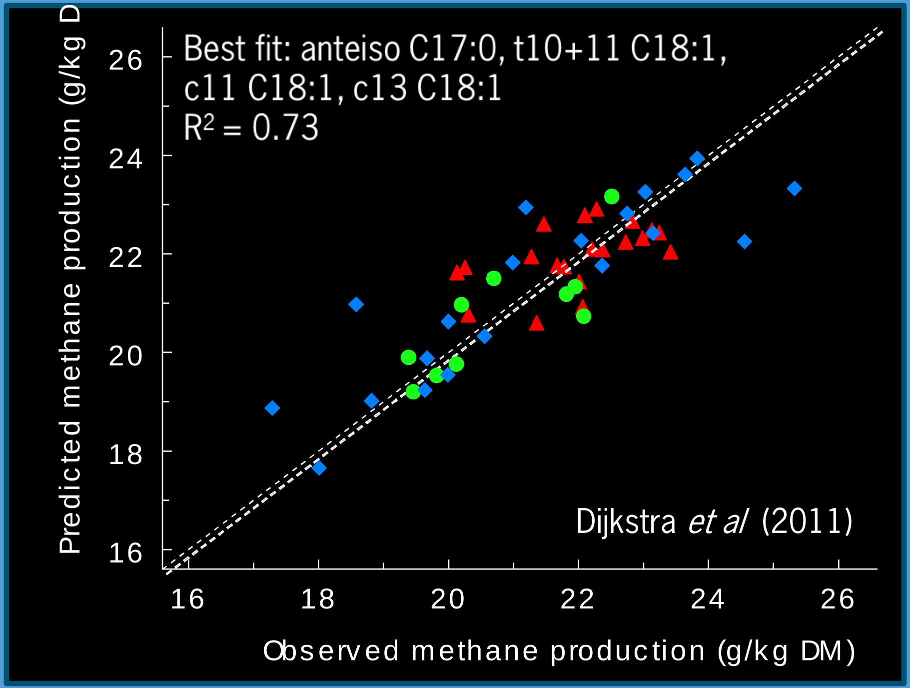
Directing on-farm, milk fat for CH_4 ?

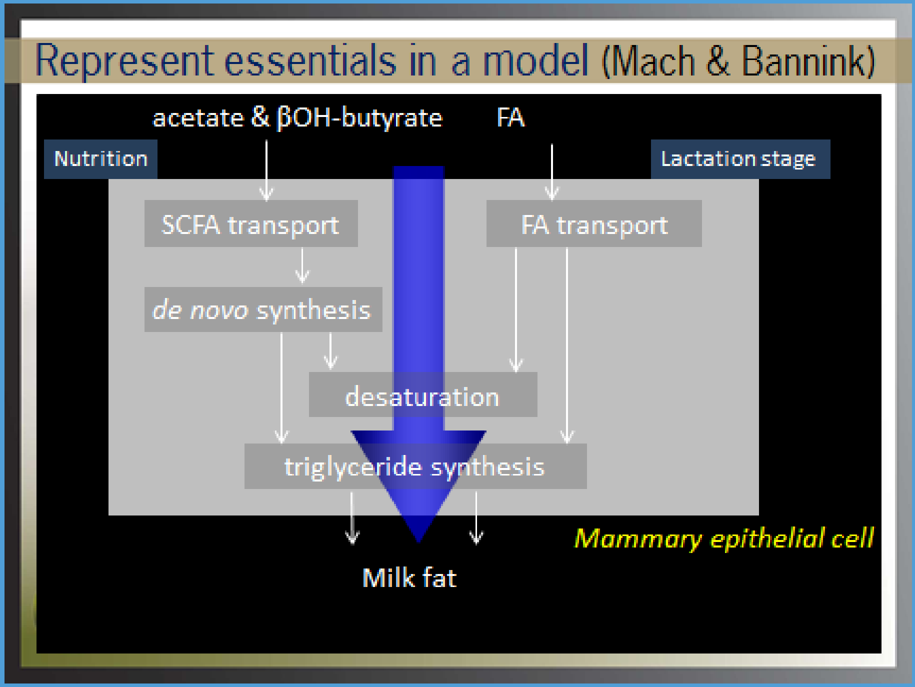
- Enteric CH_4 emission from milk fat composition
  - large variation; complex of factors
  - milk fat composition regulated
  - quantitative approaches



Bionaz & Loor (2008)

Empirical approach

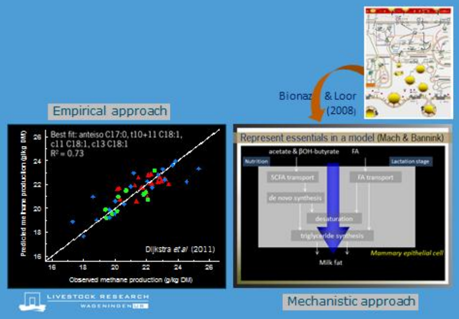


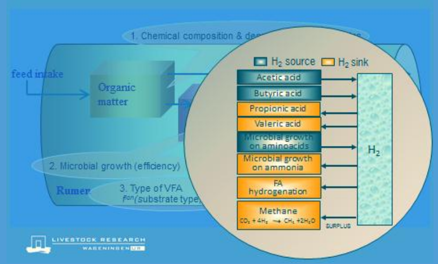


Mechanistic approach

On-farm monitoring CH_4

- Indicator to be developed still
  - To be based on reliable measurements
  - Quantitative understanding/mechanism needed to support empirical evidence ?

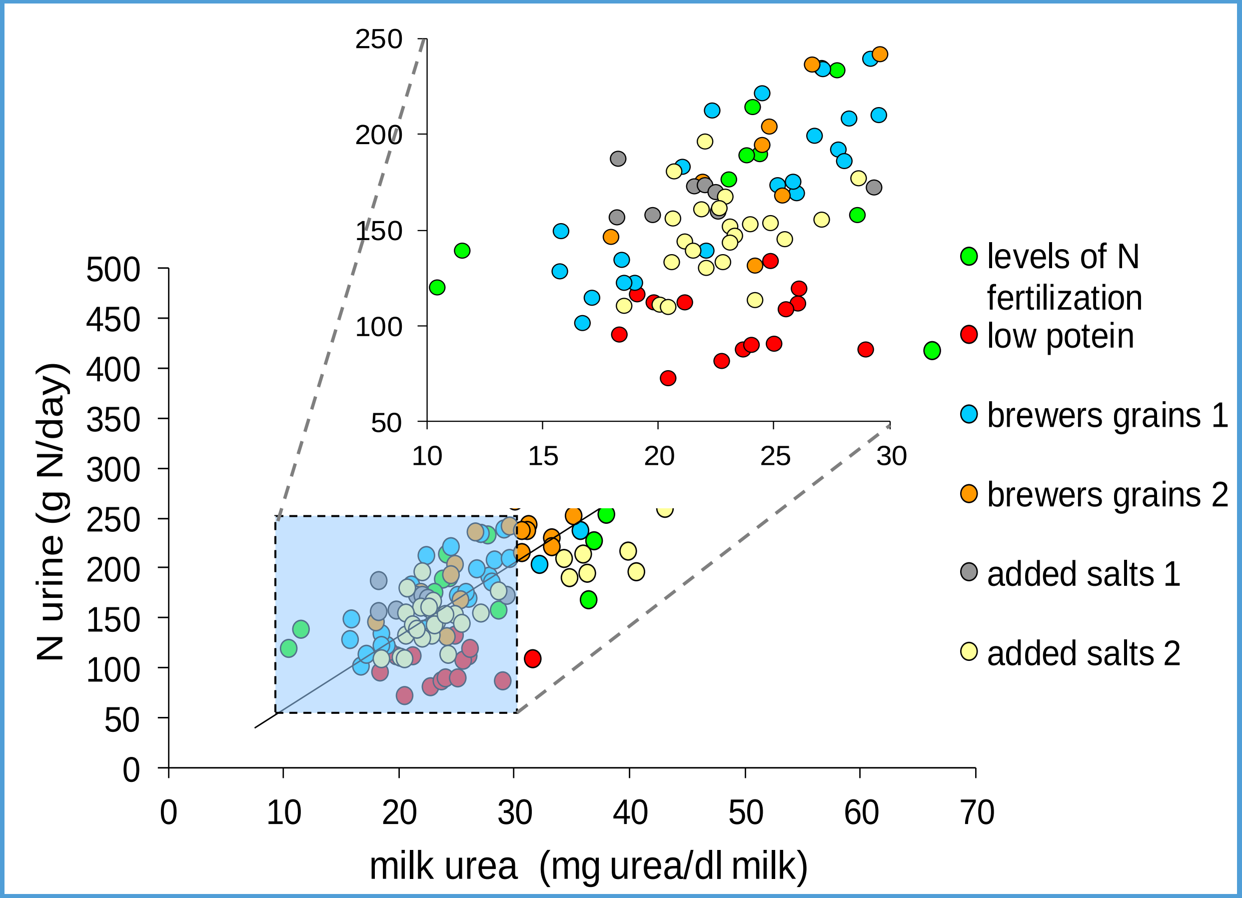




- For now, rely on CH_4 models
  - Choice of model dependent on aim
  - Accuracy needed depends on detail of interest, in particular with respect to trade-offs to N

Directing on-farm, milk urea for excreted N ?

- Milk urea relationship useful (R^2 ~ 0.8) over *total range*
- But, unreliable within *narrow range* of interest



meta-analysis N balance trials with cows
Spek *et al* (2012, in prep)

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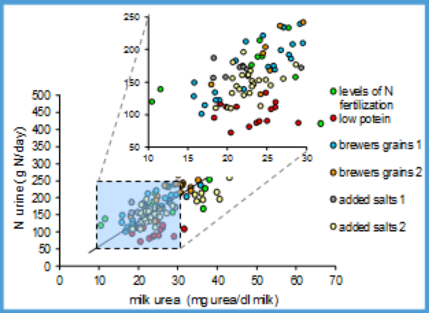
On-farm monitoring excreted N

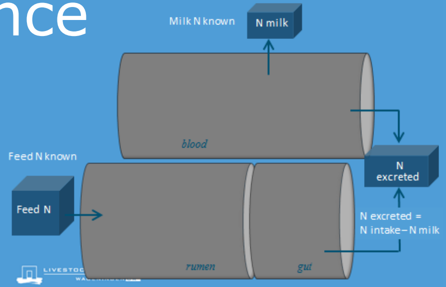
- Indicator N excretion



  - Milk urea content available
  - But much variation unrelated to N excretion
  - Many (animal) factors apart of N excretion (review Spek et al, 2012, in press)
  - Illustrative: heritability milk urea not even slightly related to N excretion

    (Šebek et al., 2007; data from 26 trials, 723 cows, 15720 wk averages)
  - Only suitable indicator if influence other factors (unrelated to N excretion) is understood and can be 'filtered' out

- For now, best rely on calculations of N balance (feed intake and production)



General conclusions

- Large variation in CH_4 emitted and N excreted per unit of milk produced, dependent on
  - type of diet and forage type
  - type and level supplementation
  - dry matter intake / production level
- At least expect that CH_4 and N are related and that trade-offs between both can be strong and (even full)
- To become conclusive on net effects of nutrition on farm GHG details on CH_4/kg milk matter
- On-farm indicators to anticipate still problematic
  - further development needed for accuracy
  - for the time, just as well rely on calculation methods

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Innovation program Low-Emission Animal Feed

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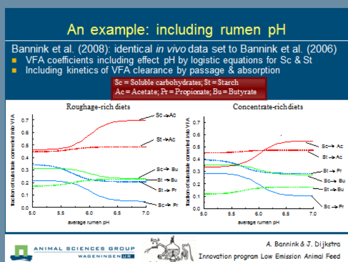
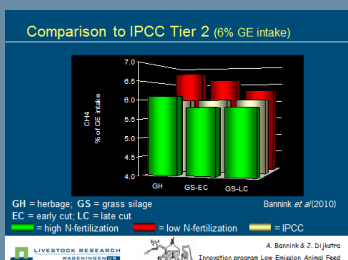
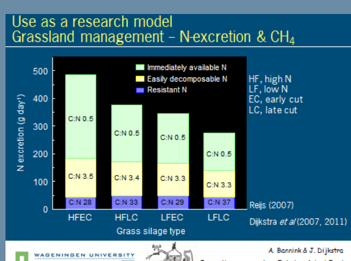
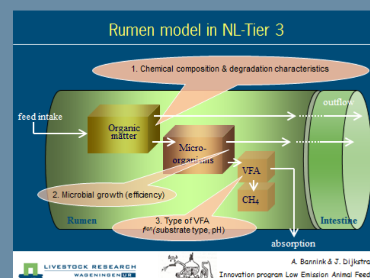
for **research & experimentation**

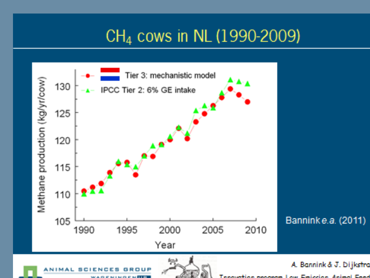




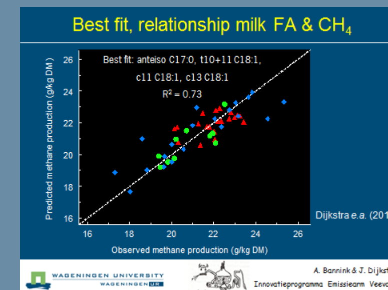


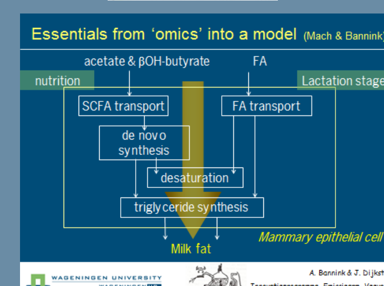
for **inventories** (Tier 3)





for **practice** (on farm)





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