MONTES DEL PLATA PROJECT
Punta Pereira – Uruguay

THE PUNTA PEREIRA CDM PROJECT - CALCULATION OF TURBON GENERATOR EFFICIENCY FOR THE BASE LINE CASE

Operação Nº 90012

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1.0 INTRODUCTION

The ACM0006 (Version 11.1) baseline methodology and the "Tool to determine the baseline efficiency of thermal or electric energy generation systems (Version 01)" do not specify a proper default efficiency factor or give any guidelines on how the efficiency should be calculated for a turbo generator. In the case of the Punta Pereira CDM project activity, an efficiency value for the turbo generator that would be used in the baseline scenario must be defined. Therefore, this document has been prepared to establish this efficiency value, ensuring the consistency with the baseline pulp mill design of the Punta Pereira project activity, a conservative emission reduction calculation of the project activity and that the proposed efficiency value complies with the normal standards of the Pulp and Paper industry in the relevant geographical region defined for the Punta Pereira project activity. It must be noted that because of these reasons, the proposed efficiency value has been designed for the specific Punta Pereira CDM project activity baseline context, and thought it could eventually be used in other contexts; it has not been designed as a general default efficiency factor.

References to supporting documents etc are given when applicable.

2.0 DEFINITION OF TURBO GENERATOR EFFICIENCY (power to heat ratio)

In "Consolidated methodology for electricity and heat generation from biomass residues ACM0006" is defined as:

TG efficiency = (power generation in MWh/a) / (Quantity of heat used in GJ/a)

With quantity of heat used should be understood the difference between the steam enthalpy to the turbine minus the feed water enthalpy to the boiler in which the steam was generated. The result is multiplied with the steam flow to the turbine.

None of the given options how to establish the TG efficiency are applicable.

However, the methodology specifies that for the mechanical and electrical losses a default value of 5% can be used.

3.0 MAXIMUM THEORETICAL TG EFFICIENCY (power to heat ratio)

The maximum theoretical TG efficiency for the base line turbo generator can easily be calculated. With maximum should be understood 100% isentropic efficiency and 100% mechanical and electrical efficiency. The calculation is summarized below:

Header conditions design		HP	MP	LP	FW	Total
Pressure	bar(a)	86	12,5	5,3		
Temperature	°C	480	200	164	120	
Feed water enthalpy	kJ/kg				501,6	
Pressure drop to/from TG	bar(a)	3	0,5	0,2		
Flow	t/h	717	273	444	717	
Heat input to TG	GJ/h					2.037
Steam data at inlet						
Pressure	bar(a)	83				
Enthalpy	kJ/kg	3342				
Temperature	°C	478				
Entropy	kJ/kg/C	6,635				
Isentropic expansion						
Pressure	bar(a)		13,0	5,5		
Enthalpy	kJ/kg		2.853,9	2.686,5		
Enthalpy drop	kJ/kg		488	167		
Header conditions						
Enthalpy	kJ/kg		2854	2686		
Enthalpy drop	kJ/kg		488	167		
Entropy	kJ/kg/C		6,635			
Efficiencies						
Isentropic efficiency	%		100,00	100,00		
Mechanical efficency	%		100,00	100,00		
Power generation	MWh/h		97,2	20,6		117,8
Power to heat ratio	MWh/GJ					0,05784

Note that the only inputs to the calculations beside inlet pressure and temperature, out let pressures are the isentropic efficiency and the electrical and mechanical efficiency.

If the default mechanical and electrical loses are taken into account the power to heat ratio will be:

Header conditions design		HP	MP	LP	FW	Total
Pressure	bar(a)	86	12,5	5,3		
Temperature	°C	480	200	164	120	
Feed water enthalpy	kJ/kg				501,6	
Pressure drop to/from TG	bar(a)	3	0,5	0,2		
Flow	t/h	717	273	444	717	
Heat input to TG	GJ/h					2.037
Steam data at inlet						
Pressure	bar(a)	83				
Enthalpy	kJ/kg	3342				
Temperature	°C	478				
Entropy	kJ/kg/C	6,635				
Isentropic expansion						
Pressure	bar(a)		13,0	5,5		
Enthalpy	kJ/kg		2.853,9	2.686,5		
Enthalpy drop	kJ/kg		488	167		
Header conditions						
Enthalpy	kJ/kg		2854	2686		
Enthalpy drop	kJ/kg		488	167		
Entropy	kJ/kg/C		6,635			
Efficiencies						
Isentropic efficiency	%		100,00	100,00		
Mechanical efficency	%		95,00	95,00		
Power generation	MWh/h		92,3	19,6		111,9
Power to heat ratio	MWh/GJ					0,05495

However the isentropic efficiency is not 100%. A normal level is around 90% for the first stage and around 80% for the second stage.

Below are presented isentropic efficiencies for a number of similar turbines as the base line turbine and as well isentropic efficiencies and mechanical/electrical efficiencies.

4.0 THE BASE LINE CASE TURBO GENERATOR EFFICIENCY, ISENTROPIC EFFICIENCIES AND MECHANICAL / ELECTRICAL EFFICIENCY

In the table below is shown as summary of the turbo generator efficiency calculation for the Punta Pereira base line case.

Header conditions design		HP	MP	LP	FW	Total
Pressure	bar(a)	86	12,5	5,3		
Temperature	°C	480	200	164	120	
Feed water enthalpy	kJ/kg				501,6	
Pressure drop to/from TG	bar(a)	3	0,5	0,2		
Flow	t/h	717	273	444	717	
Heat input to TG	GJ/h					2.037
Steam data at inlet						
Pressure	bar(a)	83				
Enthalpy	kJ/kg	3342				
Temperature	°C	478				
Entropy	kJ/kg/C	6,635				
Isentropic expansion						
Pressure	bar(a)		13,0	5,5		
Enthalpy	kJ/kg		2.853,9	2.731,5		
Enthalpy drop	kJ/kg		488	175		
Header conditions						
Enthalpy	kJ/kg		2907	2749		
Enthalpy drop	kJ/kg		435	157		
Entropy	kJ/kg/C		6,740			
Efficiencies						
Isentropic efficiency	%		89,20	89,83		
Mechanical efficency	%		95,00	95,00		
Power generation	MWh/h		82,3	18,4		100,8
Power to heat ratio	MWh/GJ					0,04947

From above can be seen that the used turbo generator efficiency, 0,04947, is lower than the theoretical highest possible at 0,05784. Below will demonstrated that the used turbo generator efficiency is higher than other methods would have given and also higher than for similar turbo generators. From this the conclusion can be made that the emission reduction calculations for the Punta Pereira CDM project are conservative.

5.0 ISENTROPIC AND ELECTRICAL/MECHANICAL EFFICIENCIES FOR RECENT TURBO GENERATOR INSTALLATIONS

The isentropic efficiency and the electrical/mechanical efficiency are normally not presented by turbo generator suppliers but can easily be calculated from normally presented data.

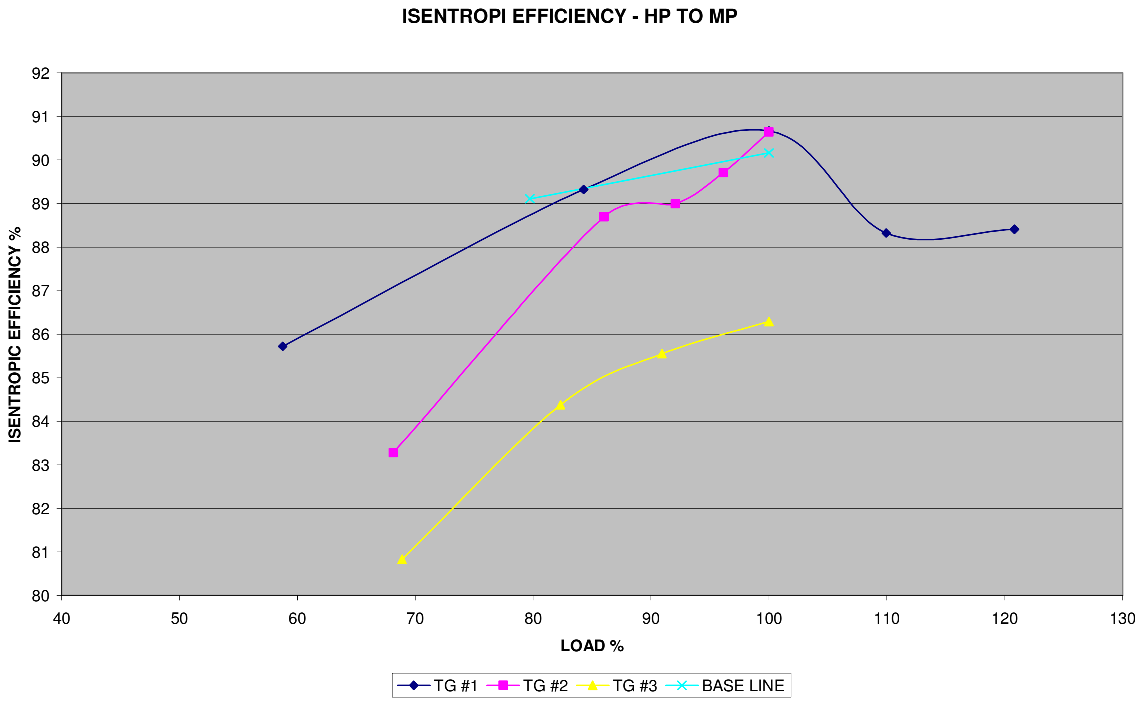
Below are data from a recent turbo generator project in Brazil summarized. All back ground data are from KSH-CRA files and can be reviewed.

It shall be noted that the design of the base line case on purpose is conservative when it comes to emission reductions. Therefore higher than normal isentropic efficiencies has been chosen to be sure that the power generation would be higher in the base line case than normally would be expected and by this the increased power generation for the project case would be lower.

It shall also be observed that the base line emissions calculations are made for the average situation. This means that the turbo generator is not operating at full load with maximum efficiency, but at a lower load and at a lower efficiency

5.1 HP-MP Isentropic efficiency

In the diagram below is shown the isentropic efficiency as function of the load for HP-steam to MP-steam for three turbo generators for the same project but from different suppliers. In the base line case used isentropic efficiency is also shown.

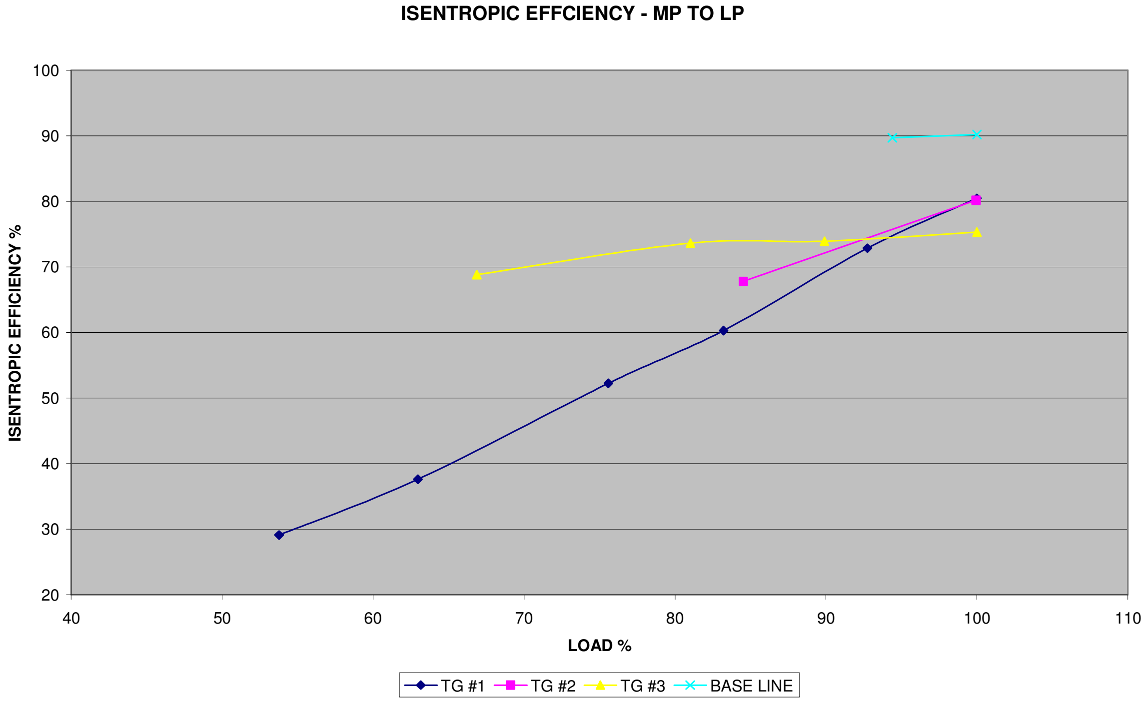


The base line data above are for average load and maximum load. It can be seen that all three of the reference turbo generators have lower isentropic efficiency at a load corresponding to the average mill production (79%) than the base line one.

From this the conclusion that the used approach for the base line case gives a conservative (low) emission reduction for the project case.

5.2 MP-LP Isentropic efficiency

In the diagram below is shown the isentropic efficiency as function of the load for HP-steam to LP-steam for three turbo generators for the same project but from different suppliers. In the base line case used isentropic efficiency is also shown.



The base line data above are for average load and maximum load. It can be seen that the three reference turbo generators all have much lower isentropic efficiency at a load corresponding to the average load.

From this the conclusion that the used approach for the base line case gives a conservative (low) emission reduction for the project case.

6.0 TYPICAL ISENTROPIC EFFICENCIES AND MECHANICAL/ELECTRICAL EFFICIENCIES – INFORMATION PROVIDED BY SUPPLIER

Siemens one of the leading suppliers of turbo generators to the pulp and paper industry has provided[1] the information below regarding isentropic and mechanical /electrical efficiencies for the load range MCR – 80% of MCR for a typical theoretical base line turbo generator.

Isentropic efficiency HP to MP	%	84,9 -76,5
Isentropic efficiency MP to LP	%	86,5-80,8
Mechanical / Electrical efficiency	%	97,72-97,60

Using the figures from Simens for MCR the result would be:

[1] See appendix A

Header conditions design		HP	MP	LP	FW	Total
Pressure	bar(a)	86	12,5	5,3		
Temperature	°C	480	200	164	120	
Feed water enthalpy	kJ/kg				501,6	
Pressure drop to/from TG	bar(a)	3	0,5	0,2		
Flow	t/h	717	273	444	717	
Heat input to TG	GJ/h					2.037
Steam data at inlet						
Pressure	bar(a)	83				
Enthalpy	kJ/kg	3342				
Temperature	°C	478				
Entropy	kJ/kg/C	6,635				
Isentropic expansion						
Pressure	bar(a)		13,0	5,5		
Enthalpy	kJ/kg		2.853,9	2.748,9		
Enthalpy drop	kJ/kg		488	179		
Header conditions						
Enthalpy	kJ/kg		2928	2773		
Enthalpy drop	kJ/kg		414	154		
Entropy	kJ/kg/C		6,781			
Efficiencies						
Isentropic efficiency	%		84,9	86,46		
Mechanical efficency	%		97,724138	97,724138		
Power generation	MWh/h		80,6	18,6		99,2
Power to heat ratio	MWh/GJ					0,04872

As can be seen the efficiency would have been 0,04872 for the Siemens turbo generator compared with 0,04947 used for the base line case turbo generator. With other words the Siemens turbo generator would generate less power than the base line case turbo generator with the same steam input. With other words the base line case power generation will result in a conservative emission reduction

7.0 CDM PROJECT ACTIVITIES IN THE REGION AND THEIR BASE LINE CASE TURBO GENERATOR EFFICIENCIES

In the relevant region there are the registered CDM project activities. The base line case turbo generator efficiencies for those three installations have been compared with the Punta Pereira base line case:

- ✓ The back pressure extraction turbine, TG2, in the Nueva Aldea CDM base line case[2] would have an efficiency of 0,04525 MWh/GJ. Note that TG3 is a straight back pressure turbine and is therefore not a relevant reference.
- ✓ The back pressure extraction turbine, TG1, in the Valdivia CDM base line case[3] would have an efficiency of 0,04235 MWh/GJ. Note that TG2 is not a relevant reference as the extraction flow is almost nill compared with 38% for the Punta Pereira base line case.
- ✓ For the UPM Fray Bentos mill the base line case[4] configuration is not very well described. However, from the information given in the PDD the base line case (reference) mills turbo generator efficiency can be calculated to 0,03746 from the presented numbers.

It has been shown that all three project cases in there PDD has specified a lower turbo generator efficiency for the base line case than Punta Pereira has specified, 0,04947 MWh/GJ, for the base line case.

The conclusion from this is that the turbo generator efficiency for the Punta Pereira base line case is ***conservative*** with respect of emission reductions.

8.0 PUNTA PEREIRA PROJECT CASE TURBO GENERATOR EFFICIENCY

The extraction back pressure turbo generator for the Punta Pereira project[5] case. 5 load points in the load range close to design are presented by Siemens. The TG efficiency has been calculated to be in the range 0,04049 – 0,04858 MWh/GJ. In all load points the efficiency is lower than the specified efficiency for the base line case at 0,04947 MWh/GJ. The opposite would be the expected as the idea with the CDM project activity is to increase the power generation. This fact is a clear indication that the difference in power generation between the base line case and the project case is on the low side and by this ***conservative*** when it comes to emission reductions.

[2] See "Nueva Aldea Biomass Power Plant Phase 2", Ref. N° 346
[3] See "Valdivia biomass power plant" Ref. N° 1787
[4] See "Fray Bentos Biomass Power Generation Project", Ref. N° 1493
[5] The information is available in Montes del Plata project files and in KSH-CRA files.

9.0 SUMMARY

The turbo generator efficiency, as defined in the CDM methodology, is normally not presented in proposals or in other turbo generator documentation but can be determined easily from the steam flow through the turbo generator and the power generation.

It has been demonstrated that the in the base line case used isentropic efficiencies are higher than documented for recent installation in Brazil. The consequence from this is that the power generation in the base line case will be higher and therefore the potential for emission reductions lower. The approach is ***conservative*** when it comes to possible emission reductions for the project case.

It has also been demonstrated that one of the major turbo generator supplier's, Siemens, normally is using lower isentropic efficiencies than the ones used in the base line case. The consequence from this is that the power generation in the base line case will be higher than it would have been using Siemens data and therefore the potential for project case emission reductions are lower. The approach is ***conservative*** when it comes to possible emission reductions for the project case.

In addition the base line case for the three relevant CDM-project activities in the region all have lower turbo generator efficiencies than the one used for the Punta Pereira base line case. This fact is one more evidence that the emissions reduction calculations are conservative.

It has also bee demonstrated that the project case back pressure extraction turbo generator has lower efficiency than the base line turbo generator. This fact is a clear indication that the difference in power generation between the base line case and the project case is on the low side and by this ***conservative*** when it comes to emission reductions.

The conclusion is that it has in this document clearly been demonstrated that the used methodology, with its inputs, to establish the turbo generator efficiency has resulted in a high turbo generator efficiency compared with what other sources would have given. The consequence from this is that the possible emission reductions will be lower than if other methods and or inputs are used. With other words the used generator efficiency is ***conservative*** when it comes to possible emission reductions for the project case.

APPENDIX A

TYPICAL ISENTROPIC EFFICIENCY AND
TYPICAL MECHANICAL / ELECTRICAL EFFICIENCY

Persson, Björn Stefan

De: Goncalves, Mara Mendonca [mara.goncalves@siemens.com]
Enviado em: segunda-feira, 26 de setembro 2011 08:27
Para: Persson, Björn Stefan
Cc: Campos, Marcio Luiz
Assunto: RES: Montes del Plata - CDM-project input for the base line turbo generator

Dear Bjorn,
For us is usual do calculate the isentropic efficiency of the turbine and after calculating total efficiency of turbine we include the losses of the bearings. See below the same table before, including one additional line with turbine efficiency before this bearing losses.

	100% load	90% load	80% load
HP-MP part of turbine	84,90%	81,00%	76,50%
MP-LP part of turbine	86,46%	85,60%	80,80%
Total efficiency of turbine	86,13%	82,85%	78,45%
efficiency turbine coupling (including bearing losses)	85,80%	82,49%	78,05%
generator efficiency (100% load)	98,10%		

If this number is still not clear for you, please let me know so I can give you a call to explain with more details.
Best regards,

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De: Persson, Björn Stefan [mailto:bpersson@ksh-cra.com]
Enviada em: sexta-feira, 23 de setembro de 2011 16:57
Para: Goncalves, Mara Mendonca
Cc: Campos, Marcio Luiz
Assunto: RES: Montes del Plata - CDM-project input for the base line turbo generator

Dear Mara,
I still don't understand. The Isentropic efficiencies will give how much energy that is converted to shaft power before the losses. The bearing losses can not be in the range of 15%. Can you please explain?
Best regards,
Bjorn

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De: Goncalves, Mara Mendonca [mailto:mara.goncalves@siemens.com]
Enviada em: sexta-feira, 23 de setembro de 2011 16:45
Para: Persson, Björn Stefan
Cc: Campos, Marcio Luiz
Assunto: RES: Montes del Plata - CDM-project input for the base line turbo generator

Dear Bjorn,
Efficiency at turbine coupling means complete efficiency of turbine considering the bearing losses.
Best regards,
Mara

De: Persson, Björn Stefan [mailto:bpersson@ksh-cra.com]
Enviada em: sexta-feira, 23 de setembro de 2011 16:37
Para: Goncalves, Mara Mendonca
Cc: Campos, Marcio Luiz
Assunto: RES: Montes del Plata - CDM-project input for the base line turbo generator

Dear Mara,
Thank you very much for the help. I have one question; can you please explain what you mean with "efficiency turbine coupling"?
I wish you a nice weekend.
Best regards
Bjorn

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De: Goncalves, Mara Mendonca [mailto:mara.goncalves@siemens.com]
Enviada em: sexta-feira, 23 de setembro de 2011 16:27
Para: bpersson@ksh-cra.com
Cc: Campos, Marcio Luiz
Assunto: RES: Montes del Plata - CDM-project input for the base line turbo generator

Dear Bjorn,
I have done a estimated calculation and I got the following numbers for efficiencies of turbine:

	100% load	90% load	80% load
HP-MP part of turbine	84,90%	81,00%	76,50%
MP-LP part of turbine	86,46%	85,60%	80,80%
efficiency turbine coupling	85,80%	82,49%	78,05%
generator eficiency (100% load)	98,10%		

If you need any additional information please let me know.

Thank you and best regards,

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De: Campos, Marcio Luiz
Enviada em: quarta-feira, 14 de setembro de 2011 14:40
Para: Goncalves, Mara Mendonca
Assunto: FW: Montes del Plata - CDM-project input for the base line turbo generator

Mara,
Pode por favor me ajudar neste tema.
Vamos falar.
Sds,
Marcio

From: Persson, Björn Stefan [mailto:bpersson@ksh-cra.com]
Sent: quarta-feira, 14 de setembro de 2011 12:56
To: Campos, Marcio Luiz
Subject: Montes del Plata - CDM-project input for the base line turbo generator

Dear Marcio,

We are, as I explained on telephone, preparing technical documentations related to Montes del Plata’s CDM project (carbon credits) for the Punta Pereira mill. The emission reduction calculations are quite complicated and are using a lot of inputs etc, which needs to be established in a stringent way. Further more all assumptions, inputs etc needs to be verified in some way. Therefore we would appreciate Siemens help as described below.

The CDM methodology use a turbo generator efficiency defined as power generation divided with the heat flow into the turbo generator. As this efficiency should be established for a fictive mill, the “base line case” that would have been installed if not the “project case” was implemented; we need Siemens help with some input for the calculations.

Knowing pressure levels and admission temperature the calculations are straight forward. However we would like to have Siemens help with typical ***ranges*** for the following parameters:

-Mechanical / electrical efficiency:
-Isentropic efficiency for the HP – MP part of the turbine
-Isentropic efficiency for the MP – LP part of the turbine.
-Typical decrease in isentropic efficiency at part load, say at 90% and 80%.

The base line turbo generator would be of type back pressure with controlled extraction for MP-steam. The design data would have been:

Admission data would have been: ~800 t/h, 83 bar(a), 478 C
MP-steam: ~340 t/h, 13 bar(a)
LP-steam: ~460 t/h, 5,5 bar(a)

Thanks in advance
Björn

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